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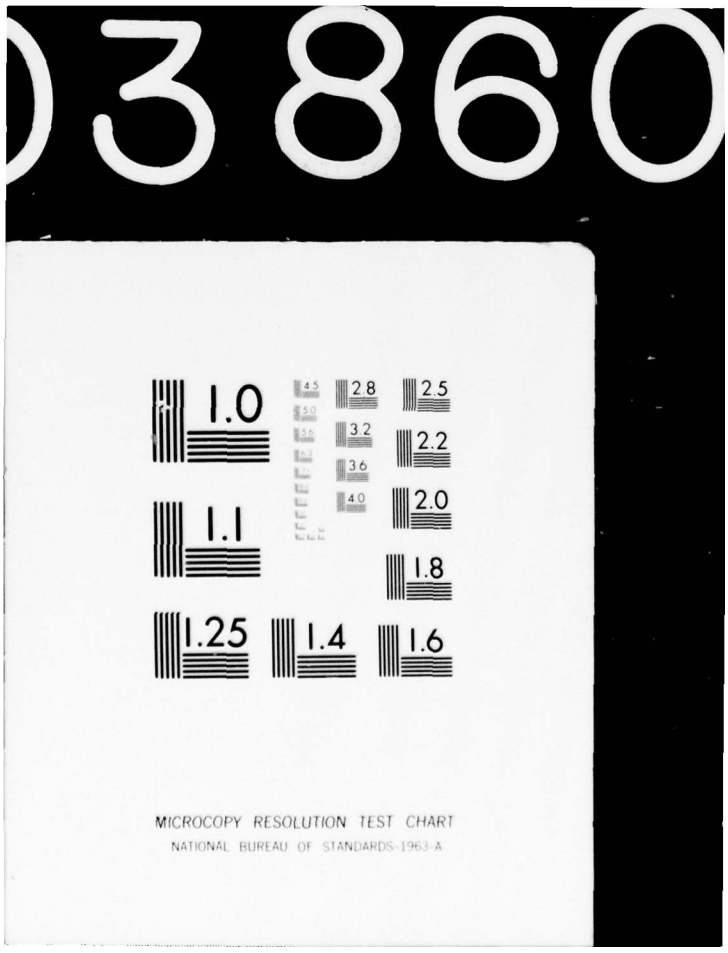
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February 1977

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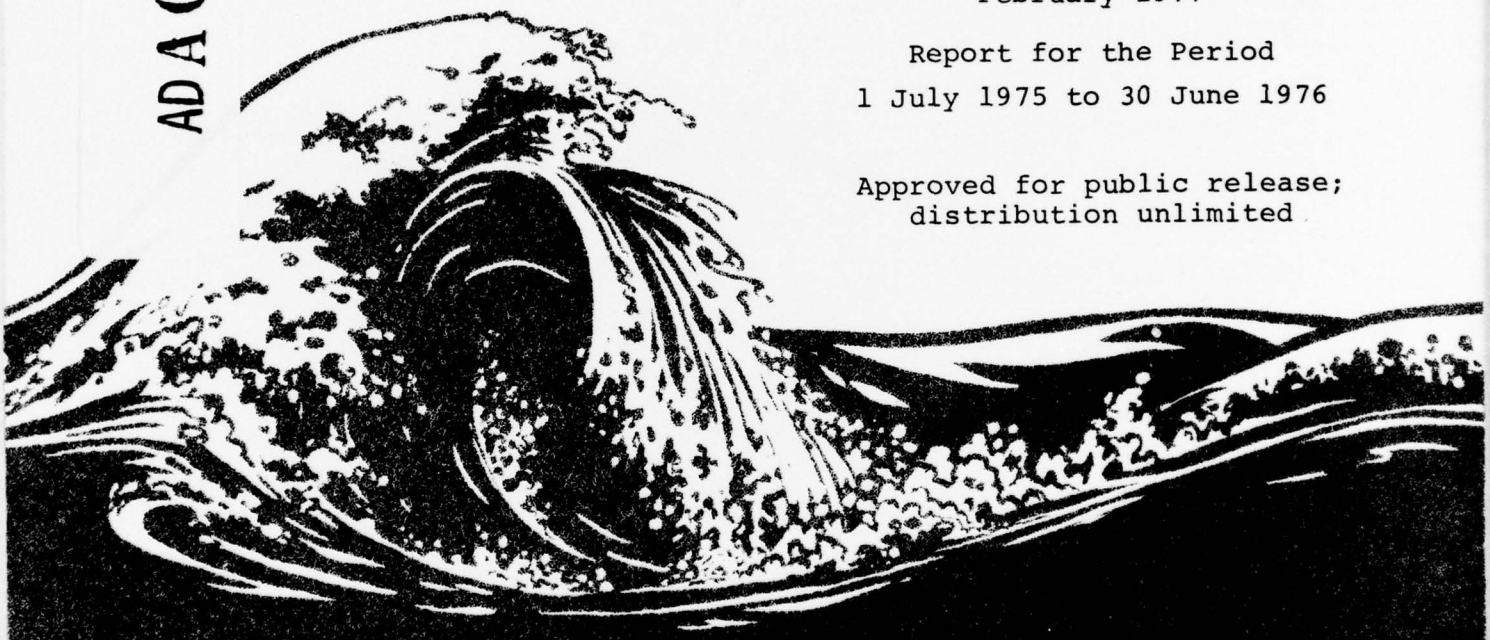

NAVAL POSTGRADUATE SCHOOL
EXCELLENCE THROUGH EDUCATION

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CALIFORNIA

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral I. W. Linder, USN
Superintendent

Jack R. Borsting
Provost

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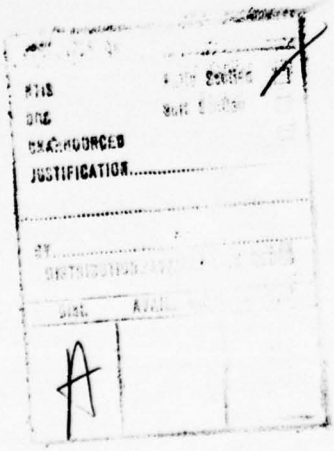

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Two hundred and twenty-six summaries of research work were carried out under funding to the Naval Postgraduate School Research Program. This research was carried out in the areas of Meteorology, Electrical Engineering, Mathematics, Operations Research, Aeronautics, Oceanography, Mechanical Engineering, and Physics. A tabulation in the index identifies the area of research and the principal investigator.

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A SUMMARY OF RESEARCH ACTIVITIES

1. INTRODUCTION AND BACKGROUND

The principal thrust of research at the Naval Postgraduate School (NPS) stems from its mission:

> To conduct and direct advanced education of commissioned officers, and to provide such other technical and professional instruction as may be prescribed to meet the needs of the naval service; and in support of the foregoing to encourage a program of research in order to sustain academic excellence.

The basic mission statement relates the research program to academic excellence. The graduate educational process necessarily involves teaching of principles which come from the frontiers of technical and professional knowledge. The research program provides the means for faculty scholarly activities at or near these frontiers and permits officer students, in the limited time available for their advanced education, to complete a meaningful thesis project. Almost all NPS students are required to submit an acceptable thesis as part of their educational program. Most of these theses are directly related to the research project of the faculty advisor. Also, as in most higher educational institutions, the research program is the activity by which the institution carries out its traditional function of generation of new knowledge. At NPS this function contributes to the Navy's RDT&E knowledge and technology base.

In summary, the three objectives of the School's research program are:

> To obtain new and valuable knowledge that contributes to the solution of Navy problems; to vitalize classroom instruction and student thesis work through continued relevance to changing Navy problems; and to maintain the professional competence of the faculty through personal involvement at the dynamic horizon of their field.

Historically, research has been important to NPS since its founding. The Navy Department General Order 21 of 9 June 1909 which directed the establishment of the School of Marine Engineering (the original NPS) also directed that the facilities of the newly established U. S. Navy Engineering Experiment Station at Annapolis be made available for research activities. With the move of NPS from Annapolis to Monterey,

the research program was first called out for separate funding. An initial grant from the Chief of Naval Research for instrumentation and equipment was obtained in 1954. This grant was continued at the same modest level through 1958. The next year it was increased to allow employment of research technicians to improve efficiency. In addition, the first research quarters were alloted to select faculty members. (During a research quarter, the faculty member has no teaching schedule and is assigned only research duties.)

As the concentration of Navy graduate education in the School increased, interest in research as an essential element in quality developed. Consequently, the Office of Naval Research (ONR) support was soon supplemented by research projects from other government laboratories, activities, and agencies. This sponsored research program, begun only modestly in 1959, has grown to be the major part of the NPS research program. Since 1965, it has consistently been larger than the ONR program.

The following sections briefly describe the program and summarize the areas of interest and competence of the academic departments and review the research output for the academic year 1975-76 (FY 76):

2. PROGRAM DESCRIPTION

a. Research in support of the Navy's RDT&E objectives:

In fulfillment of the research program objectives, NPS:

> Initiates and conducts scientific and applied research (6.1) of a long-range nature in areas of special interest to the Navy.
>
> Conducts exploratory development (6.2) deriving from scientific program areas or in other areas specifically requested by the Navy.
>
> Performs scientific research and exploratory development where uniquely qualified, for other agencies of the Department of Defense and in areas related to defense for other Federal Government agencies.
>
> Furnishes consulting services for the Navy and, where specially qualified, for other agencies of the Department of Defense and, in defense-related efforts, for other Government agencies.

To carry out the program effectively, within the educational framework, certain guidelines exist to govern acceptable projects.

First, and of primary importance, the project must have high technical merit and be consistent with quality graduate professional education.

Second, the project must be consistent with faculty competence and capabilities. In order for a particular academic department to have a significant research competence, the faculty concentrates its research efforts over a limited number of academic sub-fields and disciplines. Projects outside these areas are not usually accepted.

Third, adequate research facilities must be available. While NPS research facilities are generally excellent and up-to-date, they will not support "big science" (i.e., programs requiring facilities involving large capital investment).

Fourth, all projects must be related to areas of interest in national defense. There is no question that the emphasis in research at NPS is in military-related areas. This restriction is due less to statutory limitations (Military Procurement Authorization Act for FY 1970, Section 203, the so-called "Mansfield Amendment") than to student and faculty interests which are naturally in military-related areas.

Fifth, the time available by faculty and students to achieve useful research results is constrained by the educational program. Projects which have near-term deadlines are difficult to accomplish because of teaching and class schedule requirements.

Finally, the last guideline relates to the usefulness of the research output in the student's future. Since the student is seldom in a position upon graduation significantly to influence larger systems or management problems, thesis research should be in areas which may become useful later in his career. Consequently, knowledge or technology base problems which influence future technical or management systems are natural.

b. Research in support of the Navy's Graduate Education Program.

The student comes to the Naval Postgraduate School as a professional naval officer. The objective of the educational process at NPS is to help the student become a professional person in his chosen technical and/or management area. These areas are represented by the various curricula. The fundamental characteristics, therefore, of the education process are basically those of a professional graduate school. This means the educational process has a problem-solving orientation.

The first dimension of the process familiarizes the student with the basic problem-solving structure or morphology which

underlies professional practice. This may be summarized as follows: In dealing with a technical or management problem, the professional person must study the situation carefully in order to define the problem; he must decide how to simplify it so he can discover and apply the correct governing principles; he must then devise a plan using these skills and principles to reach a decision; finally, having reached a decision, he must check his work thoroughly and attempt generalizations. The second dimension involves learning the necessary skills and principles in each step of the problem-solving structure. These basic principles are imparted mainly through sub-professional exercise designed to demonstrate their use. These exercises result in mastery of theory, understanding of the methods of application, and knowledge of practical standards and procedures. In the final dimension, which is research oriented, the student must solve or significantly contribute to the solution of a professional problem in his chosen curriculum, that is, he must apply the structure, skills, and principles in an acceptable thesis.

The educational process outlined above is designed to graduate an officer who has an immediate competence to practice his chosen technical or management profession as well as the naval profession in general. In addition, he should have a zest for further study and learning. Finally, he should have the capability to interpret correctly and meaningfully research results in his technical or management profession.

The research program contributes to the emphasis and focus of the educational process. As mentioned above, problem-solving tends to be uniform across the professions, the specific problems vary widely. The research program provides numerous examples of the unique militarily related technical and management situations that the officer will encounter in his future career. The principles and skills as they are taught are closely related to military problems, which in turn are derived mostly from a broad research program. Further, the actual thesis work is usually part of the overall research program. Thus, the program provides a distinct and unique focus to the educational process. In addition, because of the classroom and laboratory emphasis on Navy problems, the total environment of the educational process at NPS is well matched to the student officer.

The research program contributes to the excellence of the educational process. The quality of the process is heavily dependent upon the superiority of the faculty. As mentioned before, a major objective of the research program at NPS is the maintenance of the professional competence of the faculty in their professional field.

As a graduate quality institution, NPS maintains close contact not only with the Navy community, but also with the

academic community. The research program is a primary means for maintaining this contact and interaction. The result of such interaction is a continuing interest by faculty members in other academic institutions in the Naval Postgraduate School. Specifically, a number of faculty members from other institutions have served as visiting faculty or as Postdoctoral Fellows.

c. Program Management

The research program may be conveniently devided into two parts: the Foundation Research Program and the Sponsored Research Program. The Foundation Research Program is funded by grants from the Chief of Naval Research (for 6.1) and the Director of Navy Laboratories (for 6.2). It is administered internally by a faculty Research Council which receives proposals, allocates funds, and evaluates results of prior projects. The Dean of Research is Chairman of the Research Council.

The Sponsored Research Program is administered on a reimbursable basis. Proposals are submitted to the individual government sponsors who fund or do not fund the projects according to their requirements and the technical merit of the proposed project.

DEPARTMENT OF COMPUTER SCIENCE

The research program of the Computer Science Department supports and is supported by both the Naval Postgraduate School's Computer Facility and the department's own extensive laboratories. A rapidly expanding research effort includes work in: hardware and software performance measurement methods and applications; business applications and management techniques; compiler and operating system design, implementation and optimization; microcomputer structures, software, and systems design; signal processing; computer graphics; microprogramming, multiprocessing and emulation; computer systems architecture; and software engineering.

The research program has permitted the development of a number of functional laboratories which support further research as well as instruction. These include a microelectronics laboratory where microprocessors and single board computers are interfaced with a variety of equipment to become imbedded computers; a microcomputer laboratory which includes a number of microcomputer development systems as well as a multi-user development system; a multiprocessor emulation facility consisting of a microprogrammable multi-interpreter system, for the emulation of various computer systems; and, the Naval Postgraduate School Computer Laboratory, which supports work in software engineering. The laboratory boasts both a multiprocessor system with an array processor and analog front end, to support signal processing and pattern recognition, and also a graphics capability which includes each of the principal types of graphics terminals.

MICROCOMPUTERS

The work of G. A. Kildall, U. R. Kodres, and V. M. Powers has made this department a recognized center of expertise which has contributed to Navy-wide efforts to formulate standards for microcomputers. V. M. Powers has conducted evaluations of the application of microcomputers to the Autodin communications system and to surface radar tracking. U. R. Kodres continues to explore the application of the interconnected networks of microcomputers. A multi-terminal microcomputer development system has been acquired to provide continuing support for G. A. Kildall's work in microcomputer languages and operating systems.

PERFORMANCE MEASUREMENT AND SOFTWARE RELIABILITY

N. Schneidewind has conducted extensive work in the development and application of performance measurement techniques including the analysis of multiprogrammed computer performance; the relationship between program structure and error detection; and the development of stochastic models for software error prediction.

SIGNAL PROCESSING

The research area of G. A. Rahe continues to be concerned with anti-submarine warfare and identification of nuclear explosions; however, faculty interest in image processing is developing rapidly.

ADMINISTRATIVE AND BUSINESS APPLICATIONS

C. P. Gibfried participated in a survey of management information systems employed in Naval Aviation maintenance, which produced a new standard of performance measurement. Other activities of C. P. Gibfried include an analysis of an automated system for the centralized assignment of Naval Enlisted Personnel.

COMPILER DESIGN AND IMPLEMENTATION

A significant portion of the research of L. Rich has been devoted to the development and implementation of an extended BASIC compiler on the IBM-360/67 and the PDP 11-45/UNIX systems. However, design and testing of retrieval systems is another of L. Rich's current research programs.

INTERACTIVE GRAPHICS

The principal effort in the Graphics area has been the design and implementation of software interfaces and language extension for the support of interactive graphics by G. M. Raetz. This work provided the necessary foundation for the mechanization of certain anti-submarine warfare programs on a storage tube display by G. M. Raetz and G. A. Rahe. V. M. Powers had led a faculty task group concerned with the development of new computer capabilities for three dimensional tracking and with the application of color raster-scan displays.

SOFTWARE ENGINEERING

G. L. Barksdale, Jr. continues to work in the area of operating system design and implementation. However, a current special interest area is text and graphics processing-techniques where he has already developed and installed libraries on several systems. An initial major software engineering effort resulted in a compatible and portable set of program development, maintenance, and documentation tools.

Title: Large Scale Network Optimization

Investigator: Gerald Brown, Associate Professor, Computer Science and Operations Research

Sponsor: Foundation Research Program (6.2)

Objective: To study mathematical methods leading to efficient optimization of large scale pure network cost minimization models.

Summary: An evaluation was made of many methods for pure network optimization with the view of producing extremely fast computer routines and a robust mathematical treatment of the class of problems. Several computer packages were developed for the capacitated transshipment problem and the transportation problem. Test problems as large as 20,000 equations and 50,000 variables have been solved to date with computational times and costs far less than any known competing implementation. Additional routines have been developed for network problems with nonlinear costs, transportation and transshipment problems with relatively few sources and a large number of destinations, and single commodity distribution problems imbedded in large multicommodity models. The improvements in network solution times have been exploited by larger optimization systems using pure network subproblems. The network package GNET has been distributed to many universities and to several federal and Department of Defense agencies. In addition, several hundred information requests have been received for various aspects of the results. Continuing research focuses on still larger problems, with a working goal of 1,000,000 variable models.

Publications: G. Bradley, G. Brown and G. Graves, "GNET, A Primal Network Computer System for Solution of Capacitated Network Flow Problems," copyright 1975.

Conference
Presentations: G. Bradley, G. Brown and G. Graves, "Tailoring Primal Network Codes to Classes of Problems with Common Structure," presented at the Joint National Meeting of ORSA/TIMS, Las Vegas, November 1975.

G. Bradley, G. Brown and G. Graves, "Surrogate Programming Approach to Solution of Large Scale Network Problems," presented at the Joint National Meeting of ORSA/TIMS, Philadelphia, PA, March 1976.

Title: Analysis of Binary Trees Arising from Applications in Sorting and Information Retrieval

Investigators: Gerald Brown, Associate Professor, Computer Science and Operations Research, and Bruno Shubert, Associate Professor, Operations Research

Sponsor: Foundation Research Program (6.1)

Objective: This study examines combinatorially the binary trees which arise in many computer science applications involving sorting, information retrieval and other fundamental techniques. The analysis is intended to provide information necessary to analyze algorithms based on manipulation of binary trees, thus providing a method to estimate work factors, memory region, and other characterizations of expense and efficiency of computer programs.

Summary: A closed form counting formula for the number of binary trees with n nodes and height k was developed and restated as a recursion more useful computationally. A generating function for the number of nodes given height was developed and used to find the asymptotic distribution of binary trees. An asymptotic probability distribution for height given the number of nodes was derived for equally likely binary trees. Random binary trees (resulting from insertion sorting a random string of key symbols) were counted in terms of the mapping of permutations of n symbols to binary trees of height k. An explicit formula for this number was given with an equivalent recursive definition for computational use. A generating function was derived for the number of symbols given height. Lower and upper bounds on random binary tree height were developed and shown to approach one another asymptotically as a function of n, providing a limiting expression for the expected height. The random binary trees were examined further to provide expressions for the expectations of the number of vacancies

at each level, the distribution of vacancies over all levels, the comparisons required for insertion of a new random symbol, the fraction of nodes occupied at a particular level, the number of leaves, the number of single vacancies at each level, and the number of twin vacancies at each level. A random process was defined for the number of symbols required to grow a tree exceeding any given height. Tabulations and figures were prepared for all new results.

Publications: G. G. Brown and B. O. Shubert, "On Random Binary Trees," Technical Report, NPS55Bw76061, June 1976.

Title: Aviation Maintenance Performance Measurement Systems

Investigator: CDR C. P. Gibfried, USN, Assistant Professor of Computer Science

Sponsor: Naval Air Integrated Logistics Support Center

Objective: To study and evaluate organizational and intermediate level aviation maintenance activities in order to determine the critical measures of effectiveness (are the "right" functions being performed?) and measures of efficiency (are functions being performed done well?).

Summary: Intermediate maintenance organizations at the Naval Air Stations at Pensacola, Cecil Field, Moffett Field, and Whidbey Island were visited and their "state of the art" intermediate aviation maintenance management information systems were studied and compared. Organizational maintenance activities at the Naval Air Station at Whidbey Island and Miramar were similarly analyzed and compared. A student thesis on intermediate maintenance information systems was presented to the project sponsor NAILSC; a second report concerning organizational maintenance is currently being prepared.

Thesis Directed: I. L. Olden, "A Performance Measurement System for the Aircraft Intermediate Maintenance Department Officer," Master's Thesis, June 1976.

Title: Micro Navigation Computer

Investigator: V. Michael Powers, Assistant Professor, Computer Science

Sponsor: Naval Electronic System Command

Objective: To provide laboratory facilities appropriate for evaluating trial configurations and programs, and to evaluate possibilities in the development of definitions of functions and uses of microcomputers for shipboard navigation calculations.

Summary: The support helped to provide laboratory equipment used in the theses listed below. Algorithms were programmed, in the language BASIC, which do not require the operator to enter data from tables while performing celestial fix calculations. The experience gained during this effort also contributed to the formulation of a position paper on Navy-wide standardization for microcomputers.

Publications: V. M. Powers, "A Navigational Microcomputer and Shipboard Information Distribution," Technical Report NPS-72PW76011, 7 January 1976.

Theses Directed: J. P. Moore, D. B. Rainsberger, "The Design of a Celestial Navigation Microcomputer with Thoughts on an Integrated Information Distribution System," Master's Thesis, June 1975.

L. R. B. Pedroso, "ML80=a Structured Machine-oriented Microcomputer Programming Language," Master's Thesis, December 1975.

R. D. Blocksom, Jr., "Experimentation and Design for a Computer Fiber Optic Data Line," Master's Thesis, December 1975.

Title: Aspects of Microcomputer Standards

Investigator: V. Michael Powers, Assistant Professor, Computer Science

Sponsor: Naval Electronic System Command

Objective: To contribute some NPS experience with microcomputer standardization issues to a broad-based technical statement which would be useful in formulating a policy with regard to a standard for microcomputers in the Navy.

Summary: Inputs in the form of opinions and recommendations have been provided to the sponsor. Some of these inputs have affected the structure and content of the NELC document -

> "Position paper on microprocessor/microcomputer standardization," Code 4300, NELC, December 17, 1975 -

and some have not.

Conference Presentation: V. M. Powers, "High Level Languages," a presentation made to the Navy Microprocessor Technology Task working session, 25 September 1975, Naval Electronics Laboratory Center, San Diego.

Publications: V. M. Powers, "Aspects of Microcomputer Standards," Technical Report, NPS-52Pw76101, 28 October 1976.

Title: Range Studies Program: Information Transmission, Processing and Display Group

Investigator: V. Michael Powers, Assistant Professor, Computer Science

Sponsor: Naval Torpedo Station

Objective: To advise and assist NTS in long-range efforts to plan and implement improvements in the transmission, processing and display of information in their underwater three-dimensional tracking ranges in support of programs concerned with MK 46 and MK 48 torpedoes, MK 27 and MK 30 targets, and operational weapon system tests.

Summary: During FY 76 we have continued to aid the computer and display system enhancement effort. Consideration has begun of the impact on computer resources of the use of advanced track-smoothing techniques. In-situ sensors were the object of a brief study. Principles of design, and methods of implementation, of color coding the range display on color, raster-scan graphics equipment have been investigated.

Publications: V. Michael Powers, Section 7 of "Range Study Program," O. B. Wilson, NPS-71W176081, August 1976.

Theses Directed: M. E. Bisgrove, "On the Use of Color in Raster-Scan Graphics," Master's Thesis, June 1976.

D. M. Craig, "Solid-State Digital In-Situ Acoustic Data Acquisition," Master's Thesis, December 1975.

C. H. Wilson, "Surface Search Radar Tracking by a Microcomputer Kalman Filter," Master's Thesis, June 1976.

R. L. Nesslage, "The Design of a User Interfaced for a Color, Raster-Scan Graphics Device," Master's Thesis, June 1976.

Title: Microcomputer Laboratory

Investigator: V. Michael Powers, Assistant Professor, Computer Science

Sponsor: Naval Electronic Systems Command

Summary: Equipment from various sources has been assembled into a laboratory for hands-on development work in microcomputer systems and applications. Uses include instructional laboratories and faculty and student research. The principle hardware includes two Intellec 8 Mod 80 each with dual floppy disks and CRT terminals, a Microkit with cassette tape and TV terminal, and a Sycor 440 with five terminals and a fixed disk. Communication lines to the PDP-11/50 Unix system and the duplex 360/67 system are available for interchange and cross-development. Locally developed software includes a new BASIC compiler, PDP-11 communications modules and resident software maintenance tools.

Publications: V. M. Powers, "A Navigation Microcomputer and Shipboard Information Distribution," Technical Report NPS-72Pw76011, 7 January 1976.

Theses Directed: R. D. Blocksom, Jr., "Experimentation and Design for a Computer Fiber Optic Data Link," Master's Thesis, December 1975.

L. R. B. Pedroso, "ML80: A Structured Machine-Oriented Microcomputer Programming Language," Master's Thesis, December 1975.

J. P. Moore, D. B. Rainsberger, "The Design of a Celestial Navigation Microcomputer," Master's Thesis, June 1975.

Title: Spotlight AN/UYK-20 Display Controller

Investigators: G. A. Rahe, Professor of Computer Science
G. M. Raetz, Instructor of Computer Science

Sponsor: Naval Electronics Systems Command

Objective: Develop and evaluate a AN/UYK-20 display controller to mechanize the NPS SPOTLIGHT acoustic signal processor on a Tektronix 4014 terminal.

Summary: SPOTLIGHT is an integrated signal processing and display system developed at the Naval Postgraduate School designed to improve target identification in passive acoustics. The system is presently being introduced into SOSUS. A display mechanization on the relativity inexpensive Tektronix 4014 storage tube and controlled by the Navy's standard minicomputer the AN/UYK-20 would allow more wide spread use of SPOTLIGHT. Lack of availability of a AN/UYK-20 dictated that the proposed development be conducted on the Naval Postgraduate School Computer Laboratory PDP 11 system.

A successful mechanization of SPOTLIGHT on Tektronix 4014 was produced in C language under the UNIX operating system. Complete documentation including hardware descriptions, listings of the programs and a User's Manual are available in the Naval Postgraduate School Computer Laboratory report. A demonstration of the system was provided to the sponsor and to the contractor designated to implement the system.

Thesis Directed: W. A. Fuson, "Evaluation of the Direct View Storage Display for Signal Analysis," Master's Thesis, 1976

Title: Carrier Aircraft Management Distributed Information System

Investigators: G. A. Rahe, Professor of Computer Science
G. M. Raetz, Instructor of Computer Science
D. E. Harrison, Professor of Physics and Chemistry

Sponsor: Naval Air Systems Command

Objective: To define the parameters of a distributed computer-aided command and control system which will support flight and maintenance operations of the Air Group of an Aircraft carrier. A specific objective is to demonstrate the feasibility of an interactive graphics approach to aid in information exchange and display.

Summary: A display device proposed as on with the capabilities to implement the graphics requirements for the information management system was procured. The installation, interfacing, and initial checkout were completed. The software interface requirements to make the device operational in the environment of the UNIX timesharing system on the PDP 11/50 computer system were established. A computer graphics software interface has been designed, implemented, and is operational. The completion of the display device within the constraints of the proposed distributed information system can continue.

The basic system design concept of the distributed information system for control stations in the Air Group has been accepted by the sponsor. A presentation of the system was made to personnel from Naval Weapons Center at China Lake, which has been designated to mechanize the system.

Conference Presentation: Raetz, G. M., "A Distributed Information System for Air Operations," technical paper presented at American Society of Naval Engineers' Conference, October 7-8, 1976.

Thesis Directed: S. L. Nelson, "Graphics Subsystem for a Terminal with Conic Section Capabilities," Master's Thesis, 1976.

Title: Seismic Signal Characterizations Using Graphics Techniques

Investigators: G. A. Rahe, Professor of Computer Science
C. E. Irvine, Research Associate, Computer Science

Sponsor: U. S. Arms Control and Disarmament Agency

Objective: To support the use of techniques developed by the NPS for acoustic signal processing to detect and identify seismic signals of low yield underground nuclear explosions.

Summary: Signal processing and graphical techniques developed in this program based on previous work on acoustic signals processing at the Naval Postgraduate School has been applied to a large body of seismic data. The result of this was the discovery of apparent positive differences in spectral characteristics of the P codas of earthquakes and explosions.

In previous research on detection of seismic signals from small events, discrimination of explosions from earthquakes has been uncertain and based on exclusion.

A numerical discriminant has been developed by Dr. J. Evernden, the ACDA consultant on this project, which appears to be effective to the threshold of the network detectors. It is strongly recommended that ACDA consider a follow up study to substantiate Dr. Evernden's results.

A secondary but invaluable output of this project has been the compilation of a large quantity of seismic data into a format which will allow other research pursuits in a scholarly manner.

Publications: C. Irvine and G. Rahe, "Seismic Signal Characterization," Technical Report NPS 52Ra 76081, August 1976.

DEPARTMENT OF MATHEMATICS

The major areas of research in the Department of Mathematics are: (1) Numerical analysis, (2) Optimization, (3) Applied statistics, (4) Analysis, (5) Personalized System of Instruction (PSI). The individual investigations under each of these are described briefly below.

NUMERICAL ANALYSIS

Most of the work in numerical analysis was directed toward efficient computation, particularly of problems encountered in meteorology and related fields and coordinated with the Department of Meteorology, NEPRF, and FNWC. C. Comstock, with a student, has applied finite elements to obtain better modeling of certain atmospheric waves; R. R. Fossum, C. Comstock and F. D. Faulkner are analyzing the Fourier coefficients arising in meteorology as a time series to improve prediction; R. Franke has produced an efficient code for solving stiff ordinary differential equations arising in finite-element methods in partial differential equations; Franke is developing basic functions for optimal approximation in two variables that are better suited to computation; F. D. Faulkner has developed an iterative method for the solution of the Helmholtz equation in a sphere, for the FNWC global model; A. L. Schoenstadt is analyzing the numerical effects of discretization of the primitive equation by use of Fourier transforms.

OPTIMIZATION

I. B. Russak has continued work in optimal control, deriving necessary conditions with constraints of the form $F(t,x) \leq 0$ and second-order differential equations; Russak is examining potential performance limits of envisioned air to air missiles; Faulkner and W. E. Bleick are analyzing the FNWC optimum ship routing program; H. Marks is modeling a total planning cycle for war based on the notion of ordering of war results.

APPLIED STATISTICS

P. C. C. Wang is developing a methodology for forecasting the technological threat from the Soviet and other navies for NISC; Wang and R. H. S. Stolfi are carrying out an analysis of the associated weapon system acquisition process for the most recent weapon of a given category; Wang, with several students, is modeling stochastically the sound speed fluctuation due to the existence of bubbles in the upper ocean for ONR; Wang is developing a methodology utilizing an intra-organizational structure to coordinate modernization, including the acquisition

of facilities involving high technology, and in applying this to improve modernization of certain departments at NEWSES. T. Jayachandran and Schoenstadt are developing simulation models to compare efficiency and accuracy of the Lieberman-Ross and Mann-Grubbs methods for computing relability of bounds for series-exponential system.

ANALYSIS

E. J. Stewart is investigating the algebraic and numerical properties of a method of evaluating matrix exponentials arising in the solution of differential equations; Schoenstadt has analyzed various problems in self-sustained oscillations in nonlinear systems, and the stability of solutions; D. L. Davis has developed various necessary and/or sufficient conditions for the stability of causal, recursive, "all-pole," multi-dimensional filters.

PSI

M. D. Weir has computed an evaluation of the relative effectiveness of PSI in teaching linear algebra at the NPS, a paper is forthcoming in the PROCEEDINGS of the Rocky Mountain Consortium Symposium on *Innovative Teaching in University* level mathematics.

Title: On the Stability of Multidimensional Digital Filters

Investigator: Daniel L. Davis, Associate Professor of Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: To obtain necessary and/or sufficient conditions for the stability of causal, recursive, "all-pole" multidimensional digital filters in terms of geometric inequalities between the coefficients of the transfer function which describes the filter.

Summary: Present methods for determining the stability of a filter are iterative and consequently it is difficult to determine the "cause" of filter instability in terms of the transfer function coefficients. In the present research, a new approach to the problem of filter stability has been developed by means of which it is possible to determine the precise inequalities which must hold between coefficients in order to guarantee stability. Such criteria are known for one dimensional filters and are practically essential in filter design. Although the method of this research is not yet fully developed, stability criteria for relatively complicated multidimensional filters can be derived as a result of its application. Moreover, the approach is completely general, irrespective of the order or dimension.

Publications: Daniel Davis and L. Souchon, "Stability Conditions for N-Dimensional Digital Filters," IEEE Asilomar Conference, Nov. 1975.

Title: Numerical Solution of Helmholtz's Equation

Investigator: F. D. Faulkner, Professor of Mathematics

Sponsor: Office of Naval Research, Naval Environmental Research Facility, Fleet Numerical Weather Central

Objective: Faster and/or more accurate programs for solving the Helmholtz equation.

Summary: This is part of a continuing investigation for more effective methods in solving elliptic partial differential equations. An iterative method was made up and programmed to effect the numerical solution of the Helmholtz equation in the surface of a sphere, the earth. An iteration is in two steps. First, the non-polar values are updated while the polar values are held fixed. Then the polar values are updated; this generates a secondary correction for all other terms. The problem is in use in the FNWC global model program, to solve for the surface pressure.

Publications: F. Faulkner, "The Numerical Solution of the Helmholtz Equation in a Sphere", Technical Report, NPS53Fa76025, February 1976.

Title: An Analysis of the Minimum Time Ship Routing Program

Investigators: F. D. Faulkner and W. E. Bleick, Professors of Mathematics

Sponsor: Fleet Numerical Weather Central

Objective: To analyze the minimum time ship routing program for effectiveness and improvement.

Summary: FNWC performs a ship routing service (Optimum Track Ship Routing, OTSR) for defense-related shipping. This routing is done principally by a group, called routers, who make use of the weather maps, their knowledge of climatology, and various data about the ship to chart a course. The objective is to effect the passage in minimum time with no damage.

FNWC has had for some time also a program, GMTR, that was made up to effect the same service fully automatically. The input data includes ship performance curves, tolerable wave heights, departure time and place, and destination. Available in the FNWC data bank are anticipated seas for the duration; these start with a three-day forecast and are blended into climatology over the last part of a long route. This program generates a minimum-time route, subject to the wave constraints.

All routes are updated, if it is judged worthwhile, every twelve hours. When the journey is over, the GMTR program generates a route which is based on the analyzed sea data, that is, on the recorded best-estimate of the seas. It also compares the route actually followed with the GMTR route and post-voyage route.

The first objective of the study is to determine the effectiveness of and compare the various procedures, to see where improvement might be effected and how much is feasible. A second objective was to examine various data critically to see if the problem was modeled correctly.

The analysis has been seriously delayed by many unsuspected errors in the program VERIFY which generates the required data. We have just received (December 1976) the last of the data for 1975. The initial analysis of these routes indicate that the routing service is effective

and the human routers may do a trifle better than the version of GMTR existing prior to 15 December 1976; there is not a clearcut difference.

A modification has been made to GMTR so that it can operate with a five-day forecast, rather than the present three-day. This has been checked out and appears ready to use operationally.

Publications: None

Title: The Use of Time Series in Improving Meterological Forecasting

Investigators: R. R. Fossum, Dean of Research, C. Comstock and F. D. Faulkner, Professors of Mathematics

Sponsor: Foundation Research Program (6.2)

Objective: To improve meteorological forecasting by the use of time series. Let us consider a typical meteorological variable such as the 500 mb height over the surface of the earth. It can be represented as finite Fourier series

$$\sum_{1}^{N} a_i Y_i(\phi,\theta)$$

in which ϕ is latitude, θ is longitude, and Y_i is a composite of Legendre functions in cos ϕ and trigonometric functions of θ. The coefficients a at a time t define a time series $A_n = (a_{in})$. At each time t_n, new values are generated by integrating to get predictions

$$\hat{A}_{n,1}, \hat{A}_{n,2}, \cdots \hat{A}_{n,10},$$

say, for a 5-day forecast. In the interval t , t observations are made. The predicted values, the observations, and usually, an equation such as the balance equation, are combined to yield filtered or analyzed values $\hat{A}_{n+1}$. In this way a set of corrections to predicted values is generated.

It is the purpose of this study to analyze the set of corrections

$$Z_n = \hat{A}_n - \hat{A}_{n-1,1}$$

as a time series to see if it shows trends that can be predicted to improve the forecasts. Initial work was done by Jones (1964). Since that time new techniques for integrating and for generating the Fourier series have been developed.

Preliminary programs have been generated and it appears that the numerical programs are almost ready. Jones suggested a stationary (time invariant) time series. Initial analysis of simulated data indicates that it is inadequate. A program for a series of the ARIMA type, (Auto Regressive Integrated Moving Average) has been made up.

The principal problem envisioned is to sort out the terms in Z_n that are significant, to estimate those with a series of proper low degree, and to adjust the various parameters so as to effect a suitable compromise between improvement and computational complexity.

Publications: None

Title: Numerical Solution of Very Large Sparse Systems of Stiff Ordinary Differential Equations

Investigator: R. Franke, Associate Professor, Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: The objective was to generate a computer code which could solve the very large, sparse, stiff, and implicit ordinary differential equations arising when the finite element method is used to discretize the space domain of time dependent partial differential equations. Sparse storage techniques for the matrices and an iterative linear equation solver were to be used to make efficient use of storage.

Summary: An existing program, DFASUB, due to Brown and Gear (R. L. Brown and C. W. Gear, "Documentation for DFASUB - ...," Report No. UIUCDCS-R-73-575, University of Illinois at Urbana-Champaign, Urbana, Illinois, July 1973) was selected as being an appropriate starting point. DFASUB was modified to incorporate the objective ideas and to be more user oriented. Investigation of the linear system of equations for the quasi-Newton iterates in Gear's method revealed that iterative techniques should be very efficient for their solution. This was subsequently verified when test problems executed several times faster, using less storage, than programs previously used for this type of problem. The versatility of the program allows the user to easily incorporate standard elimination techniques for solution of linear systems when necessary. The program is available and being used for production computer runs.

Publications: Richard Franke, "A Program for the Numerical Solution of Large Sparse Systems of Algebraic and Implicitly Defined Stiff Differential Equations," Technical Report #NPS53Fe76051, May 1976.

Title: Analysis and Evaluation of Procedures for Computing Lower Bounds for System Reliability

Investigators: T. Jayachandran, Associate Professor of Mathematics, and A. L. Schoenstadt, Assistant Professor of Mathematics

Sponsor: Foundation Research Program (6.2)

Objective: Analyze competing procedures available for computing lower bounds on system reliability from individual component failure data. More specifically, for two of the most commonly cited, the statistically exact Lieberman-Ross (L-R) Method and the approximately optimal method of Mann and Grubbs (M-G), (a) Determine the effect in the L-R bound of a priori ordering the component failure data, (b) Determine a measure of the amount of data unused in calculating the bound, (c) Evaluate the accuracy of the M-G procedure, (d) Study the robustness of the L-R and M-G procedures when the exponential assumption is violated, i.e., for example when the failure times have Weibull distributions instead of exponential, and (e) Determine the accuracy of M-G bounds for parallel systems and other coherent systems with different types of data such as time to failure data or success-failure data.

Summary: The statistically exact L-R method suffers from two major drawbacks. First, the computed bounds can be altered by a permutation in the order in which the components failed, even though the absolute failure times are unchanged. Second, the procedure does not utilize all the component failure data which is available, i.e., some data is "lost." Both aspects of this method were investigated in some detail. Using analytic techniques, expressions were derived for the mean and variance of the L-R bounds as a function of sample size, thus yielding insights into the effect of data order permutation. Expressions were also derived for the expected

amount of "lost" data. Then, simulation techniques were used to investigate the effect of lost data, by simulating subsystem failures, then a priori ordering the resulting failures to make maximum use of the available data. It was determined that this a priori ordering did not improve the estimating procedure.

Investigations into objectives (c) through (e) is ongoing.

Publication: A. L. Schoenstadt, "The Influence of Data Order on the Lierberman-Ross Method," NPS Technical Report #NPS53Zh76047, April 1976.

Title: Minimum Storage Solution of Capacitated Rooted Trees

Investigator: H. B. Marks, Associate Professor of Mathematics

Sponsor: Naval Postgraduate School

Objective: To study wiring networks for large controller actuated traffic signal systems.

Summary: Wiring networks for large controller actuated traffic signal systems were modeled by rooted trees. Minimum allowable wire size was sought. Using definitions of "network complexity" based on "maximal binary subtree" and "admissible solution process," it proved that there is a junction processing sequence for a complexity n network using n + 1 computer storage units, but not less. A junction sequencing algorithm was given to produce a sequence of the type guaranteed by the existence theorem. In this paper, interest was in the sequencing process; *the wiring problem was exemplary.* The algorithm was related to, but distinct from, that of Nakata and Redziejowski. This program was utilized by the Texas Highway Department and the Bureau of Public Roads. The theory was presented at a Navy Combinatorics Conference.

Publications: None

Title: Effects of Certain Configuration Parameters on a Particular Air to Air Interceptor Missile with Optimal Guidance

Investigator: I. B. Russak, Associate Professor of Mathematics

Sponsor: Pacific Missile Test Center

Objective: To examine the potential performance limits of advanced conceptual air to air interceptor missiles for the Navy. This is one part of a continuing effort concerning this topic (see annual research summary report for FY 75) and deals with the effects of configuration parameters (such as, engine size, the inclusion of aerodynamic surfaces, etc.) on performance.

Summary: The effort (begun by the investigator during FY 73) to determine performance limits of certain air to air missiles was continued. The resulting optimally guided vehicles of earlier work (see annual research report for FY 75) were investigated to determine sensitivity of perfornamce to configuration parameters. The results (such as, the fact that aerodynamic surfaces do not significantly improve performance) give guidelines for optimal missile configurations

Publications: I. B. Russak, "Effects of Certain Configuration Parameters on a Particular Air to Air Interceptor Missile with Optimal Guidance," Technical Report NPS53Ru75103, October 1975.

Title: Necessary Conditions for General Problems Involving Higher Derivative Bounded State Variables

Investigator: I. B. Russak, Associate Professor of Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: To obtain necessary conditions for solution of a complex problem in optimal control involving constraints of the form $\psi(t,x) = 0$ in which the control effects the state x through a set of second order differential equations.

Summary: By using the techniques of the calculus of variations, a set of first order necessary conditions is obtained for the above problem. The distinctions are made clear between these results and those obtained for problems in which the control effects the state x through differential equations of order not higher than one. The problem considered includes many direct applications to current naval projects, such as, optimal guidance of missiles.

Publications: None

Title: Investigation of Geostrophic Adjustment

Investigator: A. L. Schoenstadt, Assistant Professor of Mathematics

Sponsor: Fleet Numerical Weather Central and Naval Environmental Prediction Research Facility

Objective: To investigate the effect of various numerical computation schemes on the process of geostrophic adjustment.

Summary: Geostrophic adjustment is the process by which an atmosphere modeled by the meteorological primitive equations tends toward geostrophic balance. Winninghoff (1968) investigated some of the numerical consequences of discretizing (e.g. spatially centered second order finite differences) the primitive equations. This investigation extended his work. The one-dimensional dispersive wave equation was investigated using Fourier transform techniques. It was showed that discretization tended to spread the effect of local imbalances more than the differential case, and that the transient behavior in the discretized case was somewhat different than in the differential case. Further extensions are planned.

Publications: A. L. Schoenstadt, "The Effect of Spatial Discretization on the Steady State and Transient Solutions of a Dispersive Wave Equation," to appear in Journal of Computational Physics.

Title: Analysis of Reliability Estimating Methods

Investigator: A. L. Schoenstadt, Assistant Professor of Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: Analyze certain properties of the Lieberman-Ross procedure for computing system reliability bounds from subsystem (component) failure data.

Summary: The Lieberman-Ross (LR) method is a statistically exact procedure for determining lower bounds on system reliability from subsystem (component) failure data. The procedure suffers, however, from two major drawbacks. First, the computed bounds can be altered by a permutation in the order in which the components failed, even though the absolute failure times are unchanged. Second, the procedure does not utilize all the component failure data which is available, i.e., some data is "lost." Both aspects of this method were investigated in some detail. Using analytic techniques, expressions were derived for the mean and variance of the LR bounds as a function of sample size, thus yielding insights into the effect of data order permutation. Then, simulation techniques were used to investigate the effect of lost data, by simulating subsystem failures, then a priori ordering the resulting failures to make maximum use of the available data. It was determined that this a priori ordering did not improve the estimating procedure.

Publication: A. L. Schoenstadt, "The Influence of Data Order on the Lieberman-Ross Method," NPS Technical Report NPS53Zh76047, April 1976.

Title: A General Methodology for Forecasting the Technological Threat from the Soviet Navy

Investigator: Peter C. C. Wang, Associate Professor of Mathematics and National Security Affairs, and Associate Professor R. H. Stolfi, National Security Affairs

Sponsor: Navy Intelligence Support Center

Objective: To develop a general methodology for forecasting the technological threat from the Soviet and similarly organized navies of the Eurasian Communist Countries.

Summary: The methodology is based on a dynamic general structural model of the process of defense material acquisition in the Soviet Union. The outputs of the process of defense material acquisition are weapons and weapons platforms which are to the most substantial part of the technological threat. The methodology concentrates on Weapons performance characteristics (WPC) and changes in the WPCs, to define the relevant acquisition cycles and indicate the directions of future improvement.

Publications: None

Title: Stochastic Bubble Model on Sound Propagation

Investigator: Peter C. C. Wang, Associate Professor of Mathematics

Sponsor: Office of Naval Research

Objective: To model stochastically sound speed fluctuation due to the existence of bubles in the upper ocean. A specific objective is to model how low frequency sound speed fluctuation is influenced by existence of bubbles in the upper ocean. This is a continuing project with Office of Naval Research (ONR) under contract NR-042-286 on Stochastic models.

Summary: Preliminary models were developed earlier, and experimental verification of these models shows that successful predictions of maximum fluctuation of low frequency sound occurs at the resonance frequency of the bubbles. This preliminary model has been expanded in several more realistic ways. i.e., (1) Wilson's propagation formula is no longer restricted to a linear form, and (2) bubble populations are treated as random variables rather than mean values.

Publications: P. C. Wang, "Stochastic Models of the Scattering of Sound by Bubbles in the Upper Ocean," Quarterly of Applied Mathematics, January (1975)

P. C. Wang, "Asymptotics of Stirling Numbers of the 2nd Kind," Proceedings of the American Mathematical Society, (1975)

Title: Modernization Plan for the Technical Data Department of the Naval Ships Weapon Systems Engineering Station

Investigator: Peter C. Wang, Associate Professor of Mathematics

Sponsor: Naval Ship Weapons Systems Engineering Station

Objectives: To develop a methodology which utilizes an intra-organizational structure to coordinate a modernization that requires the acquisition of facilities involving high technology, and to propose a modernization plan based on mothodology developed in the above objective for the Technical Data Department of Naval Ship Weapons Systems Engineering Station to reduce technical and organizational risks.

Summary: A technical report is under preparation and it should be completed and ready for distribution sometime early in April 1977.

As a by-product of this ongoing Naval Postgraduate School study on the 1980 requirements for equipment and technology for Naval Ship Weapons Systems Engineering Station, a joint symposium by Naval Postgraduate School and Naval Ship Weapons Systems Engineering Station on Automated Production of Engineering Data and Display of Digitized Engineering Data was held on January 13-14, 1977.

Publications: None

Title:	Continuation on a General Methodology for Forecasting the Technological Threat from the Soviet Navy
Investigators:	Peter C. C. Wang, Associate Professor of Mathematics, Russel H. S. Stolfi, Associate Professor of National Security Affairs
Sponsor:	Naval Intelligence Support Center
Objective:	Statistical techniques to represent multivariate data will be studied. New techniques will be developed and implemented in order to handle intelligence analysis, and; to extend the general methodology developed to cover weapon platforms.
Summary:	The general methodology for forecasting the technological threat from red navies systematically reconstructs the Weapon system acquisition process for the most recent weapon in a particular category. On the basis of the reconstruction of the recent past, the methodology moves forward to construct the acquisition process for the future version of the selected category of weapon.
Publications:	None

Title: Discrete Transforms and Convolutions

Investigator: Carroll O. Wilde, Professor of Mathematics

Sponsor: Foundation Research Program (6.1)

Objective: Study the problem of finding the convolution operation that is appropriate for a given discrete transform, and the reverse problem of finding a transform for a given convolution.

Summary: Image science includes the total scenario of starting with a given object, forming an image of the object, transmitting the image from one location to another, detecting the transmitted image, processing the detected image, and displaying the processed image. Of primary concern for computer application is the case where the image is digitized, so that it can be represented as a discrete function over a set of lattice points, and discrete transforms and convolutions play a vital role in digital image science.

The overall objective has been approached by concentrating on one of the specific one-dimensional problems involved. Given a finite group $G = \{g_1, \ldots, g_n\}$, with g_1 the identity, we relabel the elements as $\{1, \ldots, n\}$. If x, y are n-dimensional column vectors, we define the convolution of x and y to be the vector x * y whose i^{th} component is

$$(x*y)_i = \sum_{j=1}^{n} x_{ij^{-1}}\, y_j \,.$$

The problem is to find a discrete transform, which is represented by a unitary matrix M whose columns form a representation of the original group, such that $M(x*y) = MxMy$. (The justaposition on the right denotes the linear product:

$$MxMy = \sum_{i,j} x_i y_i \, (\alpha_i \alpha_j),$$

where $\alpha, \ldots, \alpha_n$ are the columns of M.) If we define the incidence matrices $\Lambda_1, \ldots, \Lambda_n$ by

$$\Lambda_k = (\lambda_{ij}^k)_{nxn}, \text{ where } \lambda_{ij}^k = \begin{cases} 1 & \text{if } i = kj \\ 0 & \text{if } i \neq kj \end{cases},$$

then convolution can be represented by

$$(x*y) = x^T \Lambda_i y .$$

With this notation, the above problem can be reduced to that of solving a matrix equation of the form

$$\sum_{i=1}^{n} t_i \Lambda_i = \begin{pmatrix} t_1^2 & t_1 t_2 & \cdots & t_1 t_n \\ t_2 t_1 & t_2^2 & \cdots & t_2 t_n \\ t_n t_1 & t_n t_2 & \cdots & t_n^2 \end{pmatrix}$$

By equating columns, we can replace this matrix equation by n eigenvalue problems $A_i t = \lambda t$, where $t = (t_1, \ldots, t_n)^t$. Successful solution of the n simultaneous eigenvalue problems under the constraints noted above would then yield the desired matrix M.

In addition to the above delineation of the problem, results to date have included solution of the problem for almost all groups through order eight. Continuation of the study is centering on efforts to find algorithms so that the process can be extended to more complicated groups.

In conjunction with the above efforts, a continuing image science seminar has been conducted through the research period. The seminar has featured speakers from NPS, Stanford University, Stanford Research Institute and ESL, Inc., and NUC. Several colloquium lectures were given during the 1976 fall quarter at NPS, and a symposium was also held at NPS during the same quarter. Longer range goals

include formation of a dedicated image science research laboratory at NPS, and possibly development of a new curricular program if a need can be identified.

Publications: None

DEPARTMENT OF ADMINISTRATIVE SCIENCES

The Administrative Sciences Department is a newly created organizational unit responsible for academic programs designed to educate officers and DOD civilians in a variety of functional management specialties. As such, it is a large, multidisciplinary department with diverse research projects oriented to support the management tasks within the Navy and the Deparment of Defense. For ease of exposition, the program is classified into the following six areas of concentration: Systems Acquisition Management Research, Manpower/Personnel Management Research, Health Care Delivery Management Research, Technology Transfer Management Research, Management Science Research, and Resource Allocation/ Financial Management Research. The present focus of the research in these areas is summarized in the following paragraphs.

SYSTEMS ACQUISITION MANAGEMENT RESEARCH

Research in this area is wide-ranging. R. R. Judson is studying policies for the use of reliability improvement warranties. C. R. Jones' area of interest is the behavior of defense contractors, particularly in a high inflation environment. He works with M. G. Sovereign on this, who also studies the Navy budgeting process for escalation. C. K. Eoyang is developing a taxonomy of management approach to systems acquisition that will serve as one basis for improving the acquisition management system. M. B. Kline, W. C. Giauque and J. P. Hynes studied the relationship of threat and system performance requirements via decision analytic techniques for the advanced naval gun system. M. B. Kline and five systems acquisition management students performed a systems engineering management analysis of the Standard Missile Program. W. J. Haga evaluated the utilization of naval RDT&E manpower through the use of organizational structure variables. S. M. Dean is conducting an extensive study of the Navy industry shipbuilding process.

MANPOWER/PERSONNEL MANAGEMENT RESEARCH

This area encompasses not only the traditional areas of manpower and personnel management but also education and training issues, and human resources management as well as human factors research. J. K. Arima is developing an objective measure of Navy recruiter effectiveness. This is a follow-on effort to his completed study, "A Systems Analysis of Navy Recruiting." W. J. Haga investigated the relationship between various naval combat unit sizes and HRM command climate scores. W. C. Giauque identified areas in the naval education and training system where formal decision analytic methods could improve decision making. J. D. Senger studied the relationship of age and race-related attitudes

toward supervisory and peer leadership in the Navy. J. K. Arima continued his studies of the effective utilization of small arms via a series of limited purpose, live-fire field experiments. R. A. Weitzman estimated the retention probabilities for naval officers classified according to both commission source and first and second billet assignments. C. B. Derr began the development of a theoretical framework and methodology for analyzing stages in a naval officer's career. C. K. Eoyang, in conjunction with the Naval Personnel Research and Development Center, supported the development of a long-range plan for naval research in human resources management.

HEALTH CARE DELIVERY MANAGEMENT RESEARCH

W. C. Giauque, C. K. Eoyang, C. B. Derr and R. T. Harris (at MIT) examined the integration of new medical practitioner roles into the armed forces medical care delivery system. This work provides the basis for more extensive work on methods of overcoming organizational and behavioral obstacles to efficient utilization, to work on the measurement and control of quality of care and to examination of the economics of using paramedical personnel. D. R. Whipple, in association with C. K. Eoyang, C. B. Derr, K. L. Terasawa, W. M. Raike and T. A. Wyatt, provided support to BUMED and, in particular, the newly instituded Planning, Programming and Analysis Directorate in the areas of management analysis and basic research. The management analysis included analytical support for the PPBS system, team building and conflict management workshops, a management information system conceptual design, and suggested management and operational structure changes to the health care delivery system. Basic research activities included studies on the comparative costing of military vs civilian models of health care delivery by D. R. Whipple and K. L. Terasawa. These same investigators also analyzed aspects of a multiregional health care voucher system.

TECHNOLOGY TRANSFER MANAGEMENT RESEARCH

J. W. Creighton and J. A. Jolly, in association with officer and civilian thesis students, have been studying the nature of the technology transfer process. In conjunction with the Naval Facilities Engineering Command, three major activities were undertaken. First, a survey of industrial research and development budgeting effort was completed to provide a comparative baseline. Second, an analysis of the perceived reward to a receiver of technology transfer and its impact on the current predictive model of technology transfer was made. And, third, a computer-based,

management information system was developed and tested for expenditure and benefits of field innovation. In addition, for NAVMAT, several activities were undertaken with the objective of providing an information base to accelerate the implementation of output from Navy research and development laboratories and centers. Symposia were given and studied as a means of transferring technology from generator to user. A study was made of the technical transfer functions of chief project engineers. Also, a study was made of the feasibility of national/regional technology transfer R&D centers. In addition, the identification of linder agents for the introduction of safety, anti-pollution and production devices was made.

MANAGEMENT SCIENCE RESEARCH

Work in this area, while frequently done in an applied context, is more basic and transferable to a variety of applications. W. C. Giauque explored the potential use of multi-attribute utility analysis in quality determination. This technique permits a quantitative measure of quality to be developed. This exploration was part of the health care research to determine medical standards in the presence of uncertainty and of multiple, often conflicting, outcome criteria. R. A. Weitzman continued the development of predictive techniques useful in manpower/personnel research. He developed a method for testing the relative accuracy of different numerical predictions, as well as a method which estimates pattern scores. The estimation procedure was compared with a method which calculates pattern scores directly but expensively. Finally, he compared methods of selecting item sets that maximize predictive validity. The data for this research is the biographical and test data obtained from Navy enlisted men. A. W. McMasters investigated the determination of maximal flows in nonplanar networks by using dual graphs. This work has application in communications and logistics. N. F. Schneidewind continued his analysis of software with the objective of refining his techniques for determining software reliability.

RESOURCE ALLOCATION/FINANCIAL MANAGEMENT RESEARCH

The work by M. G. Sovereign summarized under Systems Acquistion Management Research and D. R. Whipple, et al., summarized under Health Care Delivery Management Research are also integral to this area of research as well. In addition, C. R. Jones and several thesis students developed a method for estimating life cycle costs for high technology systems that have never before been produced or operated. D. C. Burns continued his work on an internal control simulation useful to both managers and auditors. P. J. Parker, current occupant of the Chief of Naval Operations (OP-96) Chair in Systems Analysis, continued his consultive research for the Chief of Naval Operations and the Secretary of the Navy.

Title: Measuring Recruiter Effectiveness

Investigator: J. K. Arima, Associate Professor of Administrative Sciences

Sponsor: Naval Personnel Research and Development Center

Objective: To develop an objective measure of Navy recruiter effectiveness that could be used as a criterion for validating recruiter selection procedures and for evaluating recruiter performance, training programs, work methods, operational procedures, and enlistment programs.

Summary: The study is a follow-on to the recently completed study, A System Analysis of Navy Recruiting. The basic premise of this research is that a measure or recruiter effectiveness must include a measure of what he actually produces and a measure of what he should have produced. The latter is assumed to be dependent on managerial policy that affects recruiter activity and on the inherent potential of a recruiter's territory for generating enlistments. The strategy of research has been to obtain several measures of recruiter productivity and, using stepwise multiple regression, to determine what characteristics of the recruiter's territory best predict production while controlling for managerial policy. The productivity of recruiters in California during the period June through October 1974 was selected for study because it was not quota bound. The sample consisted of 268 recruiters who had been on production duty at one station during the entire period. They represented 111 recruiting stations in the San Francisco, Los Angeles, and San Diego Navy Recruiting Districts. The territorial variables were entirely educational statistics and data which were current and could be directly mapped on recruiting station territory. They included enrollments in several categories, the minority proportion by several ethnic groups, achievement scores of 12th grade students, and a variety of financial data indicative of the characteristics of a community. The data from 399 school districts were mapped on the territory of the 111 recruiting stations. It was found that three different equations were required to predict production in the three recruiting districts. Approximately one-third of the variability in production among recruiters could be predicted on the basis of the environmental variables. This is as much as one would hope to predict, since the remaining variance is accounted for by differences among individual recruiters in motivation, ability, skills and experience; chance factors; and measurement error. Accordingly, it was shown what a recruiter could be expected to produce could be calculated for every station within a district.

Conference Presentation:	J. K. Arima, "Measuring Recruiter Effectiveness," a symposium presentation at the annual meeting of the American Psychological Association, Washington, D. C., September 1976.
Publications:	Arima, J. K. "A Systems Analysis of Navy Recruiting," Special Report 76-3, Navy Personnel Research and Development Center, April 1976.
Thesis Directed:	R. J. Sullivan, "Developing a Measure of Marine Corps Recruiting Effectiveness," Master's Thesis, June 1976.

Title: Small Arms Field Experimentation Program

Investigator: J. K. Arima, Associate Professor of Administrative Science

Sponsor: U.S. Army Combat Developments Experimentation Command

Objective: By a series of limited-purpose, live-fire field experiments, to develop knowledge regarding factors that affect the effective utilization of small arms.

Summary: The fifth in this series of experiments was conducted to determine whether an information measure could be used to quantify the difficulty of a serial firing task involving one to several targets. The time to complete the firing task with a particular weapon could then be expressed as its information processing rate and, by inference, its handling characteristic. The theory was tested by livefire using a service .45 cal. automatic pistol and a .38 cal. revolver. Task sequences at four levels of difficulty were used, and each sequence was fired four times by eight officers familiar with the weapons. The average performance of each weapon for the three sequences requiring movement could be predicted with a multiple R of over .99, attesting to the appropriateness of the concept as a measure of handling quality.

A sixth experiment in the series was conducted on the instrumented BRAVO range at Ft. Hunter-Liggett, CA. The purpose of the experiment was to determine whether the small bracketing sight conceived by Arima and used in prior experiments would improve short range, quick fire of the M16A1 rifle under low light-level conditions (.25 foot candles). A squad of eight infantrymen individually fired at four, head-and-shoulder targets that appeared in a random order at 20 and 40 yd. with an up time of 2.5 sec. during which the first 1.5 sec. was accompanied by the simulated sound and flash of weapon firing. Analysis of the total of 320 shots showed that the weapon with the bracketing sight achieved an overall hit rate of 59.4 percent, while the hit rate of the unmodified rifle was 41.8 percent, resulting in a 42 percent better performance with the simple bracketing sight principle.

Conference Presentation: J. K. Arima, "Measuring the Fit Between Person and Equipment," Paper presented at the annual meeting of the Western Psychological Association, Los Angeles, California, April 1976.

Theses Directed: C. L. Featherstone and R. J. Scaglione, "A Feasibility Study for Determining a Small Arms Measure of Effectiveness for Handling Characteristics," Master's Thesis, September 1975.

H. L. Honbarrier, "A Field Experiment to Determine the Effectiveness of a Circular Bracketing Sight, at Low-Light Levels for the M16A1 Service Rifle," Master's Thesis, June 1976.

Title: Naval Material Command Technology Transfer

Investigators: J. W. Creighton, Professor of Administrative Science

Sponsor: Naval Material Command

Objective: To accelerate the implementation of output from the Navy Research and Development Laboratories and Centers.

Summary: The scope of this project has included almost any type of activity which would inhance the effectiveness of the Navy's R&D investments. The specific direction of the project has been toward accelerating the rate by which the output from the Navy Laboratories gets into use.

The project has been directed by Professors Creighton and Jolly and has been carried on with the assistance of some of the students in the NAVAIR Executive Management Program. The following are the specific subject areas treated under the project in FY 1976:

1. The publication of the proceedings of the June 1975 NAVMAT Technology Transfer Methodology Meeting. The work has been edited. A preliminary report has been circulated to key individuals. The final proceedings have been proof-read and should be mailed to approximately 5,000 recipients in September 1976.

2. A study has been made of the technology transfer functions of chief project engineers. This study was made specifically to apply to a test and evaluation center but the report is directed toward the responsibilities of any laboratory engineering manager to get research results into use. The work has been completed. It will appear as the thesis of Mr. Jack Grubber from the NAVAIR Test Center, Patuxent River, Maryland.

3. A feasibility study and operational plan for national and regional technology transfer R&D Centers. The objective of this study is to investigate the need for an implementation plan for the establishment of centers to facilitate the movement of technology between federal, state, and local government agencies and the private sector. A report on this sub-project will be completed in September 1976 and will appear as the Thesis of Peter S. Hughes, Naval Weapons Evaluation Facility, Kirtland Air Force

Base, Albuquerque, New Mexico, and Milton H. Olson, Naval Weapons Center, China Lake, California.

4. A study of symposia as a means for transferring technology from generator to user. This project will be complete in September and will be reported in the thesis of Mr. Donald Bennett from the Pacific Missile Test Center, Point Mugu, California, Kenneth Thornton, Pacific Missile Test Center, Point Mugu, California, and Mr. John Sweeney, Naval Air Station, San Diego, California.

Publication: None

Title: Quantification of Technology Transfer and Utilization for the Naval Facilities Engineering Command

Investigator: J.W. Creighton, Professor of Administrative Science

Sponsor: Naval Facilities Engineering Command

Summary: The scope of this project was identified by letter 19 May 1976 from Commander, Naval Facilities Engineering Command to Superintendent, U.S. Naval Postgraduate School, Ref. 031B/JTR. The following summary addressed the work that has been done in response to the identified scope:

1. A survey of Industrial Research and Development Budgeting Effort Selection, and Evaluation has been made. This will be reported as NPS Technical Report No. 54CF76092 of Mr. Howard C. Fish from the National Parachute Test Range, El Centro, California, and Mr. Joseph W. Wilson from the Pacific Missile Test Center, Point Mugu, California. This work was directed by Professors Creighton and Jolly.

2. Research has continued in the area of R&D performance motivation in relation to the linker model. One aspect of this has been completed and has been reported.

3. In an effort to develop a system for technology transfer utilization ratings for NAVFAC R&D work units,a study was undertaken to develop a system for automating the information system of a small service organization. This work was also directed by Professors Jolly and Creighton. The basic model was designed, then tried in the Field Engineering Support Office at the Civil Engineering Laboratory, Port Hueneme, with the aide of Mr. Gene Early to automate the system for keeping track of expenditures and cost benefits of field innovations. This work is to be reported on in September 1976(by Kenneth M. Suess, Naval Air Station, San Diego, California, and James F. Thaler, NAVAIR Propulsion Test Center, Trenton, New Jersey.) (Technical Report No. 54CF76091 "Demonstration of the Feasibility of Automating the Information System of a Small Service Organization Using a Generalized Computer Software Package." It is expected that this system can be adapted to rating work units at the Naval Facilities Engineering Command.

Publications: Keith E. Nuynhuis and James H. Welborn, "Analysis of the Perceived Reward to the Receiver and Its Impact on the Predictive Model of Technology Transfer," Technical Report No. 55Jo76061, June 1976.

Title: Off-Shore Drilling

Investigator: J. W. Creighton, Professor of Administrative Science

Sponsor: Harry Diamond Laboratories and U. S. Geological Survey

Objective: To attain the implementation of safety, anti-pollution, and production devices on off-shore oil drilling rigs in the Gulf of Mexico.

Summary: This project was conducted by J. W. Creighton and James A. Jolly with the help of several students from the NAVAIR Executive Management Program. The Postgraduate School segment of the project for the implementation of safety devices has been completed although the Postgraduate School will probably be asked to cooperate in the future phases.

The Harry Diamond Laboratory has been working with the U. S. Geological Survey to develop devices for safety, anti-pollution, and increased production on the oil rigs but has had little success in getting the people on the rigs to use them. The specific mission of the Postgraduate School was to develop an implementation plan and suggest the organization required. Our report to the Harry Diamond Laboratory included the following:

1. Our study of the individuals and their linker characteristics indicated that six of the U. S. Geological Survey employees were skilled at doing implementation work, with two of these having a very high degree of capability.

2. A modification of the Harry Diamond Laboratory Survey Instrument was sent to the drilling crews so that members of the drilling crews who had desires for new things and new ideas could be identified.

3. A recommendation that the higher level linkers among the Geological Survey employees be charged with the implementation responsibility, and that this group should work with the high level information receivers among the oil drilling crews to work out an implementation plan.

4. That the Geological Survey work more closely with the oil companies through the implementation organization to develop an atmosphere of acceptance, in place of the present atmosphere of resistance to the safety, and anti-pollution devices.

The Geological Survey had indicated to the Harry Diamond Laboratory that they would like to have future assistance from the Postgraduate School in the implementation of the project. It is anticipated that the earliest date this cooperation would be requested would be January 1977.

Publications: None

Title: Development of a Theoretical Framework and a Methodology for Analyzing Stages in a Naval Officer's Career

Investigator: C. B. Derr, Associate Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To develop a theory and method for studying officer career patterns

Summary: A thorough review of the existing research on career patterns lead to several hypotheses about career stages of naval officers. Further discussions with Professors Dalton and Thompson at Brigham Young University and Drs. Roberts and Wilcox at NPRDC served to clarify initial formulations. Finally, in this exploratory research, two classes of MN 3105 were surveyed. Tentative conclusions were reached as follows:

1. Stage theory is relevant but not telling
2. Various communities espouse different values and attract persons with corresponding values (e.g., technical values for NAVAIR, managerial values for Surface Warfare, security values for CEC and Supply).
3. It is presumed that at the early period of one's career one is pre-selected for higher rank by the quality of the billet he occupies,
4. Many officers are second-career oriented
5. In-depth interviews are preferred for collecting such sensitive information.

A new research proposal entitled, "Naval Officer Career and Quality of Life Study: Implications for Retention and Work Productivity," builds on this exploratory research and has been submitted to the Office of Naval Research and approved.

Publications: None

Title: Development of a Methodology for Analyzing Data Describing Officer Billets

Investigators: R. S. Elster, Associate Professor, Administrative Sciences Department, and R. R. Read, Professor, Operations Research Department

Sponsor: Foundation Research Program (6.1)

Objective: To develop and exercise methodologies useful in comparing and contrasting naval officer billets using data from job task inventories. In the long run it is hoped the results will facilitate the description of billets and help to identify educational requirements.

Summary: A job task inventory questionnaire was prepared by modifying (and abbreviating) earlier work. It was administered to 96 Navy officers (mostly students at NPS) and subjected to the techniques of factor analysis, multidimensional scaling, hierarchial clustering, and K-means cluster analysis. The last of these techniques emerged as the most useful in terms of the stated objectives. It appears that a few billet clusters (three in our data) are quite stable in that they are sharply delineated from the others and their content can be described by a few task items. The clusters of the remainder billets are not as clearly defined but can be separated in useful ways.

The follow on step is to enhance the questionnaire so that greater separation power is available in certain areas, and to apply it to a larger and more representative sample. Cross validation techniques should be included.

Publications: None

Theses Directed:

J. Lemke, Major (Fed. German Air Force), "Methodologies of Officer Billet Classification," Master's Thesis, 1976.

Title: Long Range Planning on Naval Research in Human Resources Management

Investigator: C. K. Eoyang, Assistant Professor of Administrative Science

Sponsor: Navy Personnel Research and Development Center

Objective: To provide staff support and guidance to PERS-65 in the formulation of a long range plan for research on the Navy's Human Resource Management Program.

Summary: Investigation of existing activities and functions related to the Navy's HRM Program provided an information base from which were developed preliminary recommendations for a long range HRM research plan. Two draft documents were prepared for consideration by NPROC and PERS-65: A draft Operational Requirement for HRM System Development, and a draft Navy Decision Coordinating Paper for HRM System Development.

Publications: None

Title: A Taxonomy of Systems Acquisition

Investigator: C. K. Eoyang, Assistant Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To identify basic characteristics of technical systems acquired by the military to understand the dynamics underlying the management of these systems.

Summary: The research in progress is scheduled to be completed by January 1977. To date, data for forty-eight weapon systems have been collected representing a variety of projects from the Army, Navy, and Air Force. They include aircraft, ships, missiles, and torpedoes. Statistical analyses are underway to determine the relative contribution of several variables to the total variance in cost, schedule, and performance. Preliminary results indicate that simplistic cause-effect relationships are not strongly supported by the data, although several findings suggest a few intrinsic system characteristics are significant.

Publications: None

Theses Directed:

LT D. D. Henry, "Performance Correlates of Weapon System Projects in the Military," Master's Thesis, December 1976.

Title: Decision-Making in the Naval Education and Training System

Investigator: W. C. Giauque, Assistant Professor of Administrative Sciences

Sponsor: Naval Training Equipment Center

Objective: To survey decision-making methods and organization in the Naval Education and Training Command, particularly at top management levels, and to determine the potential role of and desirability of formal approaches to selected top management decision problems.

Summary: Traditionally top management decision-making relies heavily on informal techniques--intuitive judgments by experienced managers, traditions and "rules of thumb" peculiar to each organization, or informal consensus among a group of managers. Currently there is increased interest in improving the effectiveness of decision-making in the Naval Education and Training Command not only because of the unprecidented complexity of the task but also because of the severe shortage of resources. In this study, interviews were conducted with key managers in the command staff, the support staff, and at the largest operational command. A number of areas were identified where more formal approaches to decision-making should be used. A summary of current decision-making techniques and the potential role of improved techniques are also included.

Publications: W. C. Giauque, "Decision Analysis and Its Applicator to the Naval Education and Training Command," TAEG Report #27, July 1975.

W. C. Giauque, "Organizational Decision-Making," Technical Report NPS55Gi75081, August, 1975.

Title: Studies of the Effectiveness of Paramedical Personnel Usage in Medical Care Delivery

Investigators: W. C. Giauque, Assistant Professor of Administrative Sciences, Carson K. Eoyang, Assistant Professor of Adminstrative Sciences, C. Brooklyn Derr, Associate Professor of Administrative Sciences, Reuben T. Harris, Assistant Professor, Sloan School of Management, M. I. T.

Sponsor: Department of Defense, Manpower and Reserve Affairs

Objectives: To examine the integration of new medical practitioner roles into the armed forces medical care delivery system, and identify major problem areas. This research is designed to lead into more extensive work on methods of overcoming organizational and behavioral obstacles to efficient utilization, to work on the measurement and control of quality of care, and to examination of the economics of using paramedical personnel.

Summary: We surveyed personnel in various roles in the medical systems of each of the armed services, including physicians, nurse pratitioners, nursing supervisors, administrators, and corpsmen. Our major instrument consisted of over 4000 questionnaires, covering areas of job definition, description of work setting, satisfaction with various phases of work, attitudes toward other medical roles, career plans, and demographic data. We also conducted a series of field interviews to supplement the questionnaire data. We found serious problems in the administrative structure, particulary as regards nurse pratitioners, a high degree of dissatisfaction among physician assistants regarding many aspects of their work, particulary rank, pay, status, and opportunities for continuing education, and a general lack of awareness among new health practitioners. A de facto separation of duties and patients among roles exists. Significant differences in job structuring exits among the services, indeed from place to place within each service.

Conference Presentations: William C. Giauque, C. Brooklyn Derr, Carson K. Eoyang, and Reuben T. Harris, "Studies of the effectiveness of Paramedical Personnel Usage in Medical Care Delivery," Presented at the NATO Conference in Systems Science in Health Care, Paris, France, July 8, 1976.

Title: A Multiattribute Utility Approach to Measure Quality of Health Care

Investigator: W. C. Giauque, Assistant Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To demonstrate the power of a relatively new analytic technique, multiattribute utility analysis, in determining medical standards despite the presence of uncertainty and of multiple, often conflicting, outcome criteria.

Summary: Lacking objective standards of what "good" medical care is, the assessment of quality becomes a matter largely of judgment. Insofar as judgments and opinions differ, quality becomes impossible to measure. Even in cases where medical opinion subsequently agrees on proper procedures, a quantitative measure of quality still does not exist, making rational cost/benefit analysis more difficult. The factors which make quality standards difficult to define in medicine are (1) uncertainty is nearly always a major factor, both in the diagnosis of the patient's condition and in assessing the outcome of any procedure, and (2) it is usually necessary to simultaneously consider multiple, often conflicting outcome criteria. These are precisely the types of problems that multidimensional utility theory is designed to handle. In addition, this theory can also yield a quantitative measure of "goodness" for any particular course of action one cares to analyze. In this research the potential use of this technique in quality determination was explored and developed. Two particular medical problems: treatment of suspected streptococcal sore throat and treatment of hypertension, were investigated, and preliminary quality standards developed.

Publications: W. C. Giauque, "A Multiattribute Approach to Measure Quality of Health Care," Technical Report NPS55Gi76031, March 1976.

Thesis Directed:

R. E. Kapernick, "Medical Decision Analysis: An Application in Hypertension," Master's Thesis, March 1975.

Title:	Organization Size and Command Climate of Navy Ships
Investigator:	William James Haga, Associate Professor of Administrative Science
Sponsor:	Navy Personnel Research and Development Center
Objective:	To examine structural antecedents of observed relationship of high scores on HRM Survey measures of shipboard command climate to indices of crew performance
Summary:	A preliminary zero order correlation analysis found no association between a ship's crew size and its HRM command climate scores. The same lack of association between these variables was also found in air squadrons. However, a statistically significant, but otherwise unremarkable, association was found between the size of ships' departments and the dapartments' HRM climate. This demonstrated that a structural variable such as size only affects crew attitudes at organization levels closer to the individual. Further work has been suggested, combining structural variables (mission, technology, size, age of ship) into a partial and multiple correlation analysis scheme with command climate as the outcome criterion.
Publications:	None
Thesis Directed:	L. O. Milam "The Human Resources Program and Shipboard Habitability Considerations", Master's Thesis, March 1976.

Title: Evaluation of RDT&E Manpower Utilization Through Structural Variables: Phase I

Investigator: William J. Haga, Associate Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.2)

Objective: Explore the development of structural variables as a surrogate, indirect, nonreactive indicator of appropriate use of manpower in RDT&E, using the Percentile Role Differentiation Indicator (PRDI) as a theoretical template for identifying deviations from an expected degree of complexity for varying organization sizes.

Summary: Reductions of defense budgets in current dollars by Congress, and in real dollars by inflation, compel the Navy to reduce military and civilian manpower. RDT&E activities are attractive cut-back targets for manpower specialists because of the impression that they are an area of defense support "tail" rather than combat "teeth." An intuitive approach to reducing RDT&E manpower would be an across-the-board percentage cut. Yet manpower specialists (DASD-M&RA and Navy OP-121) know this approach involves the unforeseen consequence of missing considerable "tail" while knocking out some "teeth."

The original proposal was to explore a way to give manpower specialists some assistance in distinguishing "teeth" from "tail" in terms of labeling RDT&E subunits. Phase I involved six activities:

1. Reviews of prior DOD, GAO, OMB studies of RDT&E effectiveness and recommendation. This has been done.
2. Travel to BUPERS to explore the quality and availability of structural data from RDT&E units. The Foundation grant for Phase I did not include travel money.
3. Development of a structural data report format and reporting procedures. This has not been done.
4. Exploration of computer programs for storing and processing a proposed structural

data base. This has not been done.

5. Consideration of four basic structural variables to be analyzed through the PRDI. This has not been done.

The Foundation Grant for Phase I was made in April 1975. At that time, I assumed that Louis Moore III would be employed as a consultant during the summer quarter of 1975 to complete (a) the programming of the PRDI for easy use through the input of formal organization structure data and (b) develop the PRDI algorithms under differing general assumptions about the character of organizations being analyzed. Moore was not engaged as a consultant because his contract was cancelled as a possible conflict of interest. Thusly, the PRDI was not consummated.

Travel to BUPERS was unnecessary in large part because of the discovery of Navy manpower report documents available from central sources at Norfolk and San Diego. The manning documents on a handful of Navy RDT&E organizations were acquired for use in devising "teeth" and "tail" coding methods and in developing the format of a structural data report. No objective means of making the crucial "teeth" or "tail" distinctions could be found in the reported data. The only resort was to make arbitrary coding decisions which was the very kind of decision the study aimed to prevent. Even organizing the data for simple statistical descriptions proved forbidding because of the need for considerable coding and keypunching labor.

Publications:

William J. Haga, "Probabilistic Base Generator for Role Differentiation in Formal Organizations," Journal of Mathematical Sociology, with Louis Moore III, in revision.

William J. Haga, "Probabilistic Baseline Generator for Role Differentiation in Formal Organizations," Technical Report NPS53M176521, February 1975 (with Louis Moore III).

Theses Directed:

LT Robert H. Spencer, USN, "Time Series Test of a Harmonic Series Model of Organization Differentiation," Master's Thesis, March 1975.

LCDR Michael Tanner, USN, "Structural Evolution of a Procurement Command," Master's Thesis, March 1975.

LT Steven R. Alexander, "Structural Evolution of Naval Air Squadrons," Master's Thesis, March 1975.

Title: Life Cycle Costing of an Emerging Technology

Investigators: Carl R. Jones, Associate Professor of Administrative Science, Ronald L. Johnson, Earle W. Knobloch, John M. McGrath, & Kenneth R. Michna

Sponsor: Naval Electronics Laboratory Center

Objective: To develop a method for life cycle costing applicable to an emerging technology such as fiber optic data transmission methods.

Summary: For the proper guidance of R&D expenditures and the inclusion of optical data transmission methods in operational aircraft, it is necessary to develop appropriate methods for estimating life cycle costs for alternative coaxial/twisted pair wire and optical fiber avionics. The cost performance analysis began with an investigation of the alternative measures of effectiveness possible for various coaxial/twisted pair and fiber optic systems. The approach which structures the technological and demand uncertainties of fiber optics is developed through scenarios as a means of relating costs and performance. It is suggested that Delphi and experience curve techniques be used in conjunction with ordered scenarios as a technological forecasting technique for estimation of life cycle costs of fiber optics. In addition, a review of the historical and technological background of fiber optics and their application to the Naval Electronics Laboratory Center A-7 Airborne Light Optical Fiber Technology (ALOFT) Program is included.

Publications: None

Title: Escalation Impact on DOD Budgeting and Contractor

Investigators: C. R. Jones, Associate Professor of Administrative Sciences and M. G. Sovereign, Associate Professor of Operations Research.

Sponsor: Office of Naval Research

Objective: To study the budgetary effects of escalation provisions and the effect on defense contractor conduct of various types of regulatory controls imposed by procurement practices.

Summary: To meet this objective, two research activities were undertaken. The first effort (described below) involves the budgetary effect of escalation including concepts for compensating for the uncertainty introduced into budgeting by escalation. The second effort (described below) involves those aspects of escalation provision coverage which directly affect (control) the contractor's decision process as well as impact on DOD policy on industry profits.

The measurement of inflation is central to answering the question of what is the level of real resources the Navy receives. Price changes are not the same for all commodities. There are three major alternative levels at which the inflation can be measured for budget purposes: economy-wide (total Navy budget), industry-wide (appropriation category) or individual firm (contract or project). The measurement of inflation is quite sensitive to the choice of measurement technique. For example, although DOD methods show a decreasing real expenditure trend for the Navy in recent years, if inflation is measured by the Gross National Product Deflator (GNPD), an increasing trend is seen. However, examination of individual contracts shows that price rises for some Navy expenditures have been considerably above that of the GNPD. Approaches for improved measurements at the various levels are discussed.

Utilizing the refined model of a representative defense contractor, the contractor response to incentive controls, ideological controls and coercive controls was studied. Models were developed for share-lines and weighted guideline factors (incentive controls), rate of return policies (ideological controls) and for government furnished items and progress payments (coercive controls). Combining these models with the representative defense contractor model in a situation with escalation pro-

visions permitted the study of such controls on contractor conduct. Qualitative (direction of charge) results were not obtained, but a few of the algebraically complicated complete expressions were obtained.

Publications: C. R. Jones, et al., "Life Cycle Costing of an Emerging Technology: The Fiber Optics Case," Technical Report, NPS55Js76031, April 1976.

Theses Directed: T. A. Ippel, "The Impact of Inflation on Profit as Determined by Contractual Provisions of Naval FPIF Shipbuilding Contracts," Master's Thesis, March 1976.

H. L. Leon, Jr., "The Ship Acquisition Process: An Interorganization Perspective," Master's Thesis, March 1976.

S. R. Olson, "A Computer Model to Assess Financing Provisions of Naval FPIF Shipbuilding Contracts," Master's Thesis, September 1975.

Title: Modeling a Defense Contractor

Investigator: Carl R. Jones, Associate Professor, Operations Research and Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To refine a model of a representative defense contractor and characterize the contractor's responses to exogenous influences.

Summary: Based on an earlier development of a representative defense contractor model, the following refinements were studied: the inclusion of dividends as a corporate decision variable, the market structure of subcontractors, and the contractor expectations of future events. Each of these phenomena were modeled and included in the refined version of the representative defense contractor. In addition, effort was devoted to the characterization of the contractor's responses to exogenous influences. While complicated mathematical expressions are derived, simple sign (plus or minus) results were not obtained. Thus, the contractor's responses require quantitative (magnitude) information to obtain simple direction of change (plus or minus) results. This suggests the need for a somewhat more abstract model to provide insight into contractor behavior.

Publications: None.

Thesis Directed: W. C. Ridder and M. K. Heinz, "Structure, Conduct and Performance of the U.S. Aerospace Industry," Master's Thesis, March 1976.

Title: A Systems Engineering Management Analysis of the Standard Missile Program

Investigators: M. B. Kline, Professor of Administrative Sciences, CDR C. M. Garverick, USN, LCDR G. A. Bush, USN, LCDR M. K. Heinz, USN, R. W. Doncette, NWC-China Lake, and D. C. Gay, NWC-China Lake

Sponsor: Naval Sea Systems Command

Objective: To develop a history of the evolution of the standard missile family and to analyze the management of systems engineering trade-offs of the SM-1.

Summary: This effort was undertaken as part of the project research effort by students in NPS Course SM 4301. Starting with a history of the evolution of the standard missile family, the research report documents systems engineering trade-offs made in the acquisition of the SM-1 version in the areas of system effectiveness (reliability, maintainability, performance effectiveness), production (producibility, environment, packaging), logistic support (supportability, compatibility, standardization, safety, human factors, operability, performance capability and flexibility.

Publications: None

Title: Conceptual Phase Requirements Determination Methodology and Its Application to the Advanced Naval Gun System

Investigators: Melvin B. Kline, Professor of Administrative Sciences, William C. Giauque, Assistant Professor of Administrative Sciences, and James P. Hynes, Associate Professor of Administrative Sciences

Sponsor: Naval Sea Systems Command

Objectives: To assist the sponsors in the development of the conceptual phase methodology to be used for determining Advanced Naval Gun System requirements and in structuring a decision analysis model to be used for estimating military worth in terms of threat, mission, and effectiveness parameters.

Summary: The Naval Postgraduate School (NPS) research effort to date has been involved with three main areas of concern. These are (1) development of the basic conceptual phase methodology for ANGS, (2) development of a threat analysis methodology to determine weapon characteristics necessary to defeat enemy threats and to establish a target classification hierarchy to be used for establishing decision criteria, and (3) review of the status of existing warfare and damage models and their applicability to the ANGS problem.

Accomplishments to date have been the following: (1) a generalized conceptual phase methodology has been developed leading from intelligence, operational need, and technological inputs to the defining of a quantified operational requirement. (2) An ANGS decision model derived from the basic methodological model has been structured. (3) An inventory has been made of existing damage models and their applicability to strike warfare. As a result of this examination it was discovered that existing damage models start with a description of the target and our weapon capability and determine the damage that occurs when these are opposed in combat. What is needed is the inverse of this, i.e., given the target parameters and the damage (mission kill) we would like to effect, what weaponry does it take to effect this damage. In other words, existing models flow from attack to results, we want to go from desired results back to weapon requirements. We have termed this an "inverse damage model." (4) Development of a model relating mission effectiveness to target damage to kill mechanisms and finally to weapon payload requirements has been started along with an example of its application to a specific target--a bunker.

Conference Presentations: William C. Giaugue, "Conceptual Phase Requirements Determination Methodology and Its Application to the Advanced Naval Gun System," Presented at Military Operations Research Society, El Paso, Texas, June 1976.

Publications: Melvin B. Kline, William C. Giauque, James P. Hynes, "Conceptual Phase Requirements Determination Methodology and Its Application to the Advanced Naval Gun System," Technical Report NPS 55Kx75121, December 1975.

Title: Advanced Naval Gun System (ANGS) Studies

Investigators: M. B. Kline, Professor of Administrative Science, W. C. Giauque, Assistant Professor of Administrative Science, and J. P. Hynes, Associate Professor of Administrative Science

Sponsor: Naval Sea Systems Command and Naval Surface Weapon Center

Objective: To assist the sponsors in the development of the conceptual phase methodology to be used for determining ANGS system requirements and in structuring a decision analysis model to be used for estimating the military worth in terms of threat, mission, and effectiveness parameters. To assess the application of the methodology to SIRLS.

Summary: The Naval Postgraduate School (NPS) research effort to date has been involved with three main areas of concern. These are (1) development of the basic conceptual phase methodology for ANGS, (2) development of a threat analysis methodology to determine weapon characteristics necessary to defeat enemy threats and to establish a target classification hierarchy to be used for establishing decision criteria, and (3) review of the status of existing warfare and damage models and their applicability to the ANGS problem.

Accomplishments to date have been the following: (1) a generalized conceptual phase methodology has been developed leading from intelligence, operational need, and technological inputs to the defining of a quantified operational requirement, (2) ANGS decision model derived from the basic methodological model has been structured, (3) an inventory has been made of existing damage models and their applicability to strike warfare. As a result of this examination it was discovered that existing damage models start with a description of the target and our weapon capability and determine the damage that occurs when these are opposed in combat. We are looking for the inverse of this, i.e., given the target parameters and the damage (mission kill) we would like to effect, what weaponry does it take to effect this damage. In other words, existing models flow from attack to results, we want to go from desired results back to weapon requirements. We have termed this an "inverse damage model," (4) development of a model relating mission effectiveness to target damage to kill mechanisms and finally to weapon

payload requirements has been started along with an example of its application to a specific target. It is recommended that the methodology be applied to SIRLS.

Publications: Melvin B. Kline, William C. Giauque and James P. Hynes, "Conceptual Phase Requirements Determination Methodology and Its Application to the Advanced Naval Gun System," Technical Report, NPS55Kx75121, December 1975.

Title: Determination of Maximal Flows in Nonplanar Networks by Using Dual Graphs

Investigator: Alan W. McMasters, Associate Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.2)

Objective: To develop a "dual graph" algorithm for determining the maximal flows in a nonplanar flow network having finite capacities on the arcs. This is a continuing project.

Summary: The introduction of pseudo nodes at intersection points of the arcs of a two-dimensional projection of a nonplanar flow network allows a dual graph to be constructed. The solution to the primal flow problem can then be obtained by solving for the shortest route through the dual graph subject to special constraints associated with dual arcs circumscribing each pseudo node. These constraints, although simple in form, are extremely difficult to combine with the shortest route algorithm to obtain a solution to the dual. An algorithm has been proposed which appears promising and proof of its validity is currently being sought.

Publications: None

Title: Analysis of Program Structure and Error Characteristics

Investigators: N. F. Schneidewind, Professor of Administrative Science, G. T. Howard, Associate Professor of Operations Research

Sponsor: Naval Air Development Center

Objective: To determine the relationship between a computer program's structure and the amount of effort required in the testing phase of software development. In addition, a study is underway to identify program complexity measures which may be related to the ability to find errors in a program. This is a continuing project.

Summary: A simulation model was developed to explore the relationship between program structure and the error characteristics of computer software. The software is represented as a directed graph consisting of arcs (portions of software) and nodes (merging or branching points). A single test of the software is viewed as a traversal through the software from the input node until either an error is encountered or the terminal node is reached. The path taken by an arbitrary input is selected randomly in the simulation. The original placement of errors in the software can be random or user selected. When randomly placed, the number of errors in each arc is drawn from a Poisson distribution, the parameter being dependent on the arc length. Several measures of program complexity were considered and the number of errors detected versus the number of inputs was examined. The simulation model has been used to analyze the error characteristics of some NTDS programs for which error history is available.

Publications:

G. H. Bradley, G. T. Howard, N. F. Schneidewind, T. F. Green, and G. W. Montgomery, "System Test Methodology," Vol. 1, Technical Reports, NPS55Ss75072A and Vol. II, NPS55Ss75072B, July 1975.

G. H. Bradley, T. F. Green, G. T. Howard and N. F. Schneidewind, "Structure and Error Detection in Computer Software," Proceedings AIIE Conference, pp. 54-59, 1975.

N. F. Schneidewind and T. F. Green, "Simulation of Error Detection in Computer Programs," Proceedings of the Symposium on the Simulation of Computer Systems, National Bureau of Standards, pp. 101-105, 1975.

T. F. Green, N. F. Schneidewind, G. T. Howard, and T. Pariseau, "Program Structures, Complexity and Error Characteristics," Proceedings of the Computer

Engineering Conference, Microwave Research Institute, Polytechnic Institute of New York, 1976.

Title: A Study of Age and Race Related Attitudes Toward Supervisory and Peer Leadership in the United States Navy

Investigator: John Senger, Professor of Administrative Sciences

Sponsor: Naval Personnel Research and Development Center

Objective: To determine if the attitudes of younger sailors are relatively more influenced by their peer (work) group than are older sailors, and to further ascertain if the individual's race also affects these attitudes. Results of the study could provide useful information relative to the supervision of younger sailors.

Summary: A review of the literature suggests the general hypothesis that the attitudes and perceptions of young people differ from those of their elders, particularly in relationship to their peers. To examine this hypothesis an attitude survey data for a large sample of Navy personnel is being examined to determine if, indeed such differences do exist.

From the data examined to date it appears that there is generally a steady increase in the positiveness of attitude toward peers and supervisors as age increases. This holds for survey attitude questions referring to both supervisors and peers. It was found that both older and younger sailors answer more positively the questions relating to supervisors than they do those relating to peers with the following exceptions: in those questions not relating to work, e.g., friendliness, listening, encouragement of ideas, the younger sailor reacts more positively to his peer leadership than to his supervisory leadership. This trend is particularly marked among the youngest (17-20 year old) group.

Racial differences between Whites and Blacks show the Black attitudes to be consistently less positive than those of the Whites. This difference tends to decrease consistently with age, except among the 30-35 age group whose attitudes to be somewhat less positive than expected.

There appears to be some evidence to support the hypothesis that the younger sailors'

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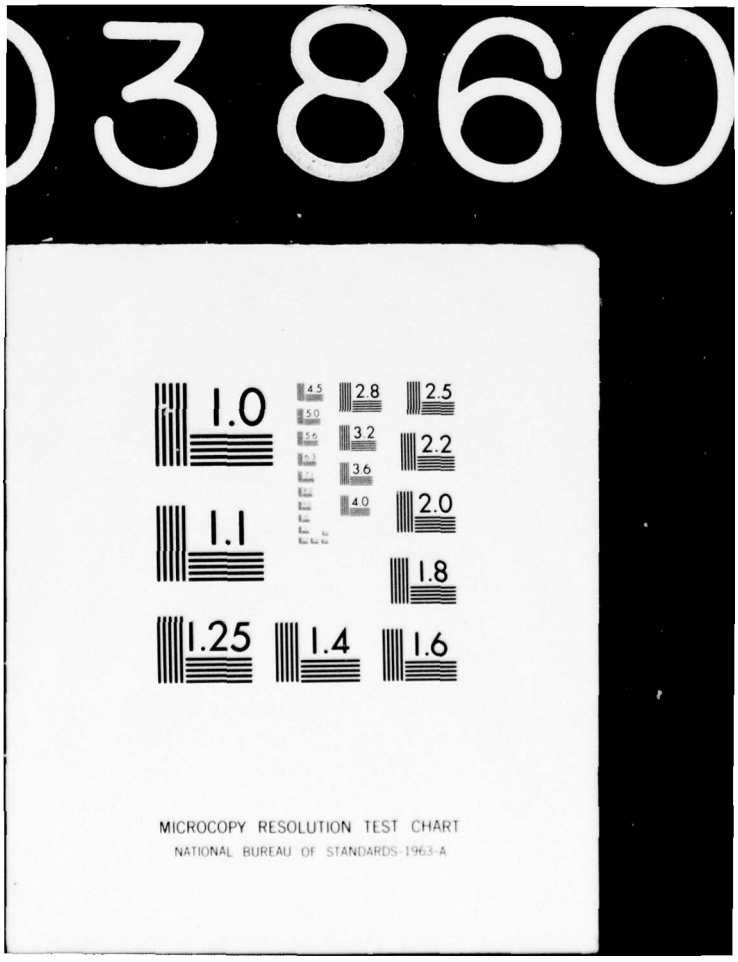
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attitudes toward their peers differ from those of older sailors.

Publications: None

Title:	Occupational Structures and Methodologies
Investigator:	R. A. Weitzman, Associate Professor of Administrative Science
Sponsor:	Naval Personnel Research and Development Center
Objective:	To compare methods of selecting item sets that maximize predictive validity (Part of a continuing program).
Summary:	Methods exist for the stepwise selection of binary test (correct/incorrect) or biographical (yes/no) items to maximize predictive validity. Sequin (in which the predictor score is the total number of correct answers to the selected items) and PAIN (in which the predictor score for the pattern of binary responses to the selected items) are examples. This research will compare the efficiency and effectiveness of sequin and pain as well as other methods (already developed) on biographical and test data obtained from Navy enlisted men.
Publications:	None
Thesis Directed:	Jackson, J. Q., "A Programme for the Tailored Selection of Response Patterns," Master's Thesis, 1976.

Title: Officer Career Continuance

Investigator: R. A. Weitzman, Associate Professor Administrative Sciences

Sponsor: Naval Personnel Research and Development Center

Objective: To estimate retention probabilities for Naval officers classified according to both commission source and first and second billet assignments.

Summary: This research will prepare and apply a computer program to the data on 16,000 Naval officers in order to evaluate a method already developed for achieving the objective described above when the number of officers falling in specific three-way classification cells may be too small for reliable estimation by ordinary means.

Publications: None

Title: Superiority of Fit

Investigator: R.A. Weitzman, Associate Professor of Administrative Science

Sponsor: Naval Postgraduate School

Objective: To develop and illustrate a method for testing the relative accuracy of different numerical predictions.

Summary: Achievement of the objective described above required reformulation of the traditional structure of a statistical test. The method developed is sequential and yields a decision in favor of one prediction or the other with a total probability of error specifiable in advance of the test.

Publications: Weitzman, R. A., "Superiority of Fit," Technical Report NPS54Wz76091, 1976.

Title: Pattern Analysis Applied to Retention Data: Comparison of PAIN and STRAIN

Investigator: R. A. Weitzman, Associate Professor, Administrative Sciences Department

Sponsor: Foundation Research Program (6.1)

Objective: To develop STRAIN, which estimates pattern scores, and compare it with PAIN (already developed), which calculates pattern scores directly.

Summary: A "pattern score" is a score assigned to an individual who has a specific pattern of responses to a set of binary items. The acronyms PAIN and STRAIN stand for Pattern Analysis Item Nominator and STRuctural Analysis Item Nominator, respectively. The method of estimation used by STRAIN is to set mth-(and perhaps lower)-order covariances $E(X_1-M_1)(X_2-M_2)\ldots(X_m-M_m)$ among the binary items equal to zero. Different from PAIN, STRAIN can obtain estimates of pattern scores for response patterns that no member of the estimation sample has. The results, obtained from retention data on Navy enlisted men, suggest that these estimates may be quite reliable. Further research is necessary, however, to strengthen this conclusion.

Publications: None

Title: Analysis of Elements of the Military Health Care Delivery System

Investigators: David Whipple, Associate Professor of Administrative Science, Assistant Professor Carson Eoyang, Associate Professor C. B. Derr, Assistant Professor K. L. Terasawa, Associate Professor William Raike, Assistant Professor Tom Wyatt,all of Administrative Science

Sponsor: Naval Bureau of Medicine and Surgery

Objective: To provide guidance to BUMED, and to the staff of the newly instituted Planning, Programming and Analysis Directorate (PPA) of the Bureau relevant to the effective and efficient achievement of their stated organizational objectives. Additionally, to the extent feasible given the agreed upon budget and the demands that timely response to the above tasks would place upon the available NPS resources, we were to identify and execute appropriate research projects which would serve as inputs to the PPA agenda for their future activities.

Summary: We may describe the substance of this effort under three headings describing the different types of effort involved:

1. The "management analysis" function which dominated efforts during these months of the contractual relationship with BUMED. The major elements of this vector include:

   (a) The team Building Seminar held by the Study Group for the entire PPA staff at Bethesda, July 1975;

   (b) The follow-up Conflict Management Workshop held in Arlington, January 1976;

   (c) The production of our "Quick and Dirty Analysis of the Phase I Boeing Report" for Code 023, (April 1975);

   (d) Evaluation and input regarding the use and value of Management by Objective (MBO) in BUMED and PPA throughout 1975;

   (e) Construction of a suggested set of "short course" possibilities for PPA staff to be given by Postgraduate School personnel;

   (f) Provision of analysis, suggestions, and evaluations of the Code 022 efforts to develop the most appropriate Management Information System (MIS) for BUMED under PPA auspices;

(g) A Preliminary Analysis of the Military Health Care Study (MHCS) report for logical consistency, September 1975;

(h) Our in-depth analysis of the final version of the MHCS report and our suggested positive responses to it in terms of possible changes in the management and operational structure of the Navy's health care delivery system, April 1976;

(i) Assistance in organizing the PPA/BUMED Long Range Planning Session to be held in Virginia in June, 1976.

2. Our more traditional research projects were limited by the short run needs of PPA to the production of the following reports:

(a) "On the Comparative Costing of Military vs Civilian Models of Health Care Delivery," NPS Technical Report NPS55WpTc, by Professors Whipple and Terasawa, November 1975;

(b) "Analytical Aspects of a Multi-Regional Health care Voucher System," by Professors Whipple and Terasawa, April 1976.

3. The support activities performed include the monitoring of the dynamic literature and unpublished suggestions of health care systems researchers pertaining to the analysis and management of health care delivery systems, public and private sector, and the investigators and institutions involved. To this end we initiated new, and maintained former, contacts with those who may at present, or in the near future, be able to provide direct assistance and ideas to projects upon which we may embark. Additionally, we, in many instances,identified potential sources of data and operational experiences in both the military and private health care sectors, which we believe will prove valuable in our work for BUMED.

Conference Presentations: D. Whipple and K. Terasawa, "Analytical Properties of A Multi-Regional Health Care Voucher System" presented at Eastern Economics Association Meetings, April 1976, Bloomsburg, PA. and at the Mid-West Regional Science Association Meetings, May 1976, Bowling Green, Ohio.

D. Whipple, "Revolution vs. Evolution in Health Care Delivery," presented at Association for Humanistic Psychology Meeting, August 1975, Estes Park, Colorado.

D. Whipple and K. Terasawa, "On the Comparative Costing of Military vs. Civilian Models of Health Care Delivery," presented at NATO Conference on Systems Science in Health Care Delivery, July 1976, Paris, France.

Publications: None

Thesis Directed: W. C. Truesdell and M. S. Duny, "An Analysis of National Health Planning and Resource Development Act of 1974 and Its Impact on Health Care Delivery," Master's Thesis, June 1976.

Title: User Satisfaction Survey

Investigator: E. A. Zabrycki, LCDR, SC, USNR, Assistant Professor of Administrative Sciences

Sponsor: Office of the Assistant Secretary of Defense

Objective: To develop, administer, and analyze the results of a survey to measure the satisfaction of users with the contract administration services provided by both the Defense Contract Administration Services (DCAS) and Plant Cognizance activities.

Summary: In June 1975, the OASD (I&L) requested that a study be performed to improve current contract administration policies and procedures because of the changing DOD procurement environment. There were indications that manpower resources might be more effectively used and greater demands and responsibilities placed on the Defense contractors. This research project was the third part of the OASD (I&L) study. It involved the development of a questionnaire which was determined as the best method to efficiently sample a large number of government buying activities. This approach permitted identification of specific problem areas, and provided a broad response of general attitudes and opinions toward CAS services. Such an approach also highlighted fundamental/recurring problems in each functional area that could be characterized as DOD-wide or service-intensive. With the printing of 1,000 questionnaires, 274 were allocated for each Service's buying offices and 130 questionnaires to the Defense Supply Agency (DSA) buying acitvities. The 274 questionnaires for each Service were distributed based on a proportion of frequency they appeared on the contract administration activities users' listings. The DSA questionnaires were allocated to three DSA activities, DPSC, Philadelphia--60, DESC, Dayton--36, and DCSC, Columbus--34. The percentage of return was 96.7%, and the large population sampled offers confidence of the questionnaire results.

Summary of Survey Results

Functions	Performance Rating	
	DCAS Favorable	Service Cog. Favorable
Contract Administration	72%	79%
Production Management	67%	73%
Quality Assurance	64%	70%
Engineering Support	47%	56%

On satisfaction surveys of this type, a favorable performance rating of 70% or higher would be desirable to achieve adequate confidence to support an overall favorable response. The DOD procuring activities ratings of the four primary CAS functions indicated that the engineering support area received the least favorable user response; however, it also reflects that their overall confidence in CAS performance was low.

Recommendations: An informational device of this type be regularly employed to achieve better user feedback and improve CAS performance.

Certain traditional CAS tasks be performed by buying activities, particularly in areas of technical support and financial reporting.

Upgrade the CAS work force to cope with today's technology through a program of formal education and on-the-job training.

Establish a rotational/interchange program between DOD buying offices and Contract Administration activities for procurement personnel.

Publications: Department of Defense Study, "Forward Look," 23 November 1976.

Thesis Directed: Brian T. Hogan, Gary H. Monteith, "A Survey and Analysis of the Users' Evaluation of Contract Administration Services," Master's Thesis, June 1976.

DEPARTMENT OF OPERATIONS RESEARCH

Operations Research is a multi-disciplinary field, a fact which is reflected by the variety of areas covered by the sponsored research of the faculty. The topics can be grouped into the broad areas of basic research in the techniques of operations research and it's applications to military problems. The techniques are mathematical programming and stochastic modeling. The applications areas are computers and information processing, combat models, manpower and personnel, human factors and resource allocation.

MATHEMATICAL PROGRAMMING

Mathematical programming represents the major deterministic tool of operations research and the Naval Postgraduate School contributes to the profession through its basic research in the area.

Joint research by Professor Gordon Bradley and Professor Gerald Brown sponsored by the Office of Naval Research and of Professor Bradley by the National Science Foundation has led to the development of extremely fast mathematical programming codes which exploit the special structure of certain optimization problems. The researchers are now investigating application to problems of approximately one million variables.

Under foundation funding, Professor James Hartman has extended his previous work in non-linear, non-convex mathematical programming to include the case when roundoff errors are significant and also to include non-separable problems. Professor Gerald Brown has tested the GNET code developed above with a variety of network optimization problems with 20,000 equations and has added the capability to deal with fixed charges, non-linear costs and multi-commodity problems.

STOCHASTIC MODELING

The other major approach in Operations Research is probabilistic model building and statistical analysis. Several faculty contribute to this area.

Professor Donald Gaver, under National Science Foundation funding, has developed several models using a diffusion approximation technique for communication and computer systems and maintenance and repair systems. Professor James Esary has

continued his study of transformation techniques for analyzing networks of components which fail randomly. This work, under ONR support, led to his invitation to a major symposium on nuclear safety. Under foundation funding, Professor Harold Larson pursued development of optimal techniques for selecting the bias parameter in ridge regression, a new statistical technique.

Finally, Professor Peter Lewis derived properties for new stochastic point processes based on similarities to time series which he has previously examined. This work was supported by ONR.

COMBAT MODELS

The application of operations research to the development and employment of weapons reflects both the origin of the profession and the special role of the Naval Postgraduate School in the field.

Professor James Taylor has continued his fundamental studies of warfare via Lanchester-type differential equations and the optimization thereof for ONR. Several of his numerous publications won the yearly prize of the Military Applications Section of the Operations Research Society of America along with Professor Parry. Professor Sam Parry has been working directly with the Army Armor and Engineer Board on computer simulations of mobility's effect on tank survivability.

Professor Neagle Forrest has directed the Strategic Systems Project Office research program at the Naval Postgraduate School. In addition, he has produced programmable calculator routines for magnetic anamoly based on a new detection model for the Naval Air Development Center.

Search models for a moving target were developed by Professor Alan Washburn under foundation funding.

Professor Donald Barr developed models for evaluation of a Marine system for position locating.

HUMAN FACTORS

The application of operations research to man-machine systems is known as human factors study. The Human Factors Laboratory is a major resource for student thesis work as well as Navy research. Professor Gary Poock investigated aircraft accident factors for the Navy Safety Center. Additional work in that area under CDR L. E. Waldeisen was supported by the Naval Air Development Center.

COMPUTER AND INFORMATION PROCESSING

The computer has made possible large-scale examination of operational problems. Research in this area is of concern to several faculty.

Professor Donald Gaver has developed a model of the operating system of a multi-programming computer for the Defense Communication Agency.

Professor Gilbert Howard has cooperated with Professor Norman Schneidewind of the Administrative Sciences Department in studies of software reliability for the Naval Air Development Center.

Professor Bruno Shubert with Professor Gerald Brown has examined the structure of sorting and information retrieval processing under foundation funding.

MANPOWER AND PERSONNEL

The major cost of the U. S. military is for personnel. Planning and analysis of the personnel system is, therefore, of considerable interest.

Professors R. W. Butterworth, P. R. Milch and R. R. Read have developed interactive computer systems for analyzing Navy enlisted personnel data for the Bureau of Personnel. Related work for the Marine Corps has been carried out by Professor Kneale Marshall.

Professor Donald Gaver along with Professor William Giauque of the Administrative Sciences Department has pursued studies of the personnel retention system for the MARDAC organization of OSD.

Professor Robert Read, under foundation funding, has cooperated with Professor Richard Elster of the Administrative Sciences Department on a structure and data for describing Navy officer billets.

RESOURCE ALLOCATION

Many of the tools of operations research are applicable to the question of how to allocate resources in the military.

Professor Kneale Marshall was asked by the Chief of Naval Education and Training to devise indices for measurement of the training curricula of the Navy. He also worked with Professor

Russell Richards on modeling budget processes as queueing systems. Professor Richards has also devised inventory control procedures for the Naval Electronics Command.

Professor M. G. Sovereign has participated with Professor Jones of the Administrative Sciences Department in the ONR supported study of the impact of inflation on Navy budgeting. Professor Sovereign also directed the Conceptual Analysis Project supported by the Operations Research/Systems Analysis curriculum sponsor, OP-96.

Title: Statistical Models for Evaluating Position Location Systems and Bombing Systems

Investigator: D. R. Barr, Professor of Operations Research

Sponsor: Naval Electronic Systems Command

Objective: To develop evaluation methodology and models for use in assessing performance characteristics of certain hardware systems being developed for use by the Marine Corps.

Summary: Data obtained in tests of two PLRS (Position Location and Reporting System) configurations at Camp Pendleton, California, were analyzed. Some characteristics of the two systems were determined, including identification of factors significantly affecting system errors. Methods of using the TPQ-27 bombing system for radar bomb scoring were investigated, and several problems requiring further research were identified.

Conference Presentation: D. R. Barr and T. D. Burnett, "A Sequential Test Based on Sample Medians," Paper delivered at the annual meeting of the American Statistical Association, Boston, Mass., August 1976.

Publications: D. R. Barr and T. D. Burnett, "A Radar Bomb Scoring Method," Technical Report NPS55Bn76031, March 1976.

Theses Directed: W. Sevon, "An Analysis of the Position Location and Reporting System's Performance Characteristics," Master's Thesis, March 1976.

T. Chen, "Relative Robustness of Several CEP Estimators," Master's Thesis, March 1976.

Title: Large Scale Optimization in Network Models

Investigators: Gordon Bradley, Associate Professor of Operations Research, Gerald Brown, Associate Professor of Computer Science

Sponsor: Office of Naval Research

Objective: To extend the usefulness of highly efficient minimum cost pure network optimization systems by improving the mathematical treatment of the underlying algebraic theory. Data structures responsible for the efficiency of primal network codes such as GNET are not intrinsically suggested by the mathematical notation commonly used for optimization models. Development of a coherent mathematical context within which to view pure network models should lead naturally to generalization of network results to more complicated optimization models with imbedded networks, or other special problem structure.

Summary: The highly efficient network package GNET was extended to incorporate several new advances in data structures promoting the exploitation of special network structure. Two common examples with special structure are problems with many more sinks than sources, and pure transportation problems: The highly rectangular problems arise in production-distribution models with a few factories and many outlets, and transportation problems are a fundamental specialization of network distribution models. The new extensions to GNET (formerly the fastest code known) improved solution times by as much as 300 percent. In concert with the development of new data structures, the mathematical approach to primal networks was critically examined, and several fundamental theoretical results were derived with widely varying algebraic techniques. The usefulness of these alternate viewpoints was tested by implementation of several non-pure network applications with imbedded network structure. A nonlinear objective function was accommodated both by separable and local linearization methods. These two packages were used for solution of a goal programming model for (Army officer) personnel assignments. A version of GNET was provided as a subroutine for researchers developing optimization software for distribution system design with multiple commodities. One version of this system is now being used by the DOD Material Distribution System Study Group. The success of these, and other applications is due in part to the unprecedented economy and feasible problem sizes of these network codes. The network package GNET has been distributed to many universities and to several Federal agencies. Attention is now focused of solution of extremely large problems (in the one million variable range) and on further

development of more general models exploiting network substructure. This is a continuing research project.

Conference Presentations: G. Gradley, G. Brown and G. Graves, "A Comparison of Storage Structures for Primal Network Codes," presented at the Joint National Meeting of the Operations Research Society of America and the Institute for Management Sciences, Chicago, May 1975.

G. Bradley, G. Brown and G. Graves, "Tailoring Primal Network Codes to Classes of Problems with Common Structure," presented at the Joint National Meeting of ORSA/TIMS, Las Vegas, November 1975.

G. Bradley, G. Brown and G. Graves, "Surrogate Programming Approach to Solution of Large Scale Network Problems," presented at the Joint National Meeting of ORSA/TIMS, Philadelphia, March 1976.

Publications: G. Bradley, "Survey of Deterministic Networks," (Special Report) AIIE Transactions, 7, 3, September 1975.

G. Bradley, G. Brown and G. Graves, "GNET, A Primal Network Computer System for Solution of Capacitated Network Flow Problems," copyright 1975.

Thesis Directed: Y. P. Cheong, "Network Transformations and Some Applications," Master's Thesis, December 1975.

Title: Integer Linear Programming and Network Optimization

Investigator: Gordon H. Bradley, Associate Professor of Operations Research

Sponsor: National Science Foundation

Objective: To investigate the algebraic structure of integer linear programming problems and to develop algorithms to compute optimal solutions to these problems. To investigate algorithms to solve large scale network optimization models including the capacitated transshipment, transportation and assignment problems.

Summary: Fixed order enumeration methods for integer linear programming problems are simple and often effective for solving practical size problems. This class of algorithms can be improved by studying the structure of the enumeration path as the algorithm proceeds. Computational testing of these ideas has shown that this approach can significantly improve performance of the algorithms.

The capacitated transshipment, transportation and assignment problems model many important defense and commercial applications including the transport of goods, assignment of personnel, and bid evaluation. Data structures, algebraic and graph theoretic methods were investigated for the efficient solution of large-scale problems. For these network models an extremely efficient algorithm was developed. The results of this investigation were used to develop a FORTRAN program for capacitated pure network problems. Test results with problems with 10,000 nodes and 35,000 arcs show that the program is as much as 50 times faster than commercial linear programming algorithms. The copyrighted program is available to other researchers and Department of Defense agencies.

Conference Presentations: G. Bradley, "Fixed Order Enumeration Methods," presented at the Joint National Meeting of ORSA/TIMS, Las Vegas, November 1975.

G. Bradley, G. Brown and G. Graves, "A Comparison of Storage Structures for Primal Network Codes," presented at the Joint National Meeting of the Operations Research Society of America and the Institute for Management Sciences, Chicago, May 1975.

G. Bradley, G. Brown and G. Graves, "Tailoring Primal Network Codes to Classes of Problems with Common Structure," presented at the Joint National Meeting of ORSA/TIMS, Las Vegas, November 1975.

G. Bradley, G. Brown and G. Graves, "Surrogate Programming Approach to Solution of Large Scale Network Problems," presented at the Joint National Meeting of ORSA/TIMS, Philadelphia, March 1976.

Publications:

G. Bradley, "Survey of Deterministic Networks," (Special Report) AIIE Transactions, 7, 3, September 1975.

G. Bradley, G. Brown and G. Graves, "GNET, A Primal Network Computer System for Solution of Capacitated Network Flow Problems," copyright 1975.

Theses *Directed:*

Y. P. Cheong, "Network Transformations and Some Applications," Master's Thesis, December 1975.

J. J. Timar, "Modeling, Transformations and Scaling Decisions in Constrained Optimization Problems," Master's Thesis, March 1976.

R. J. Waterman, "An Evaluation and Comparison of Three Nonlinear Programming Codes,"Master's Thesis, March 1976.

Title: Navy Enlisted Personnel Modelling Project

Investigators: R. W. Butterworth, Paul R. Milch and Robert R. Read, Associate Professors and Professor of Operations Research

Sponsor: Naval Personnel Research and Development Center and Bureau of Naval Personnel

Objective: To improve existing management tools, and to introduce new tools, for the Navy's enlisted personnel system. Specific objectives were concentrated on the Navy's FAST model for strength and advancement planning, namely evaluating potential improvements in this model, and developing alternate models to augment the Navy's capability in this area.

Summary: The advancement process for the enlisted Navy was studied in order to understand how this process might be better modelled. This task was done to support the Navy's FAST model. Preliminary data analysis of the promotion process historically has indicated a wide variation in practices, year to year.

A modified regression model was found to be sufficiently accurate to predict advancements by LOS using the volume of advancements and the inventory by LOS as predictor variables. This model was then used to find a relationship between the mean LOS of advancements and the volume of advancements. Such relationship was not readily verifiable from the data. Somewhat contrary to expectation, it was found that the mean LOS of advancements may be either a decreasing or an increasing function of volume. Whether it is the former or the latter depends on the pay grade, rating and fiscal year in question. A possible explanation for both the decreasing and increasing type of behavior is also offered.

An interactive personnel planning model, MINIFAST, was formulated, coded, and delivered for operational testing and evaluation. The model, beginning with the selection of a subject rating, calculates an estimate of the yearly gains and losses of personnel, the promotions within, and the new recruits to the rating. A policy affecting the personnel system can be quickly evaluated for its effect on overages and shortages of personnel, its effect on the advancement system, and the need for new personnel, for multiple years in the future.

Thus MINIFAST is an interactive planning model for rapid policy evaluation.

A preliminary investigation of ridge regression as a technique for predicting personnel system losses and gains was completed, and a further study is now scheduled.

Publications: Richard W. Butterworth, "Minifast, An Interactive Model of the Navy's Enlisted Personnel System," Technical Report, NPS-55Bd76081, August 1976.

Thesis Directed: A. R. Walker, "An Analysis of the Naval Personnel Pay Predictor (Enlisted Model) A Basic Pay Projection Model," Master's Thesis, September 1975.

Title: Probability Models for Reliability Analysis

Investigator: J. D. Esary, Professor of Operations Research

Sponsor: Office of Naval Research

Objective: To refine and develop the probability models which are the basis for practical methods of reliability analysis and prediction.

Summary: Phased Missions: In a phased mission the pertinent system configuration (block diagram, fault tree, etc.) changes as the mission proceeds through a sequence of distinct phases (periods in which the operational requirements on the system and possibly the stresses on its components are different). Computing the probability of success for a phased mission is more complex than doing a series of standard reliability calculations, one for each phase. A principal result previously obtained is a transformation which makes the analysis of a phased mission equivalent to the analysis of a single-phase mission, so that (at least in principal) existing computer programs can be used. The transformation has been used to study various approximations to the probability of mission success.

Subsequent work has included provision in the analysis of phased missions for an "operational readiness" phase, i.e. a phase of uncertain duration prior to the inception of the active mission in which maintenance can be performed. Phased missions with phased sub-missions branching away from the main mission trunk have also been considered. The mission of an FBM submarine has "operational readiness" and branching sub-mission aspects.

The methods are being applied to reactor safety systems by the Aerojet Nuclear Company under an ERDA contract.

Mixtures of Life Distributions: Mixtures of life distributions arise when manufacturing processes produce items with different innate survival potentials, or when the service environments of identical items vary. The properties of mixtures of life distributions are relevant to the use of "burn-in" as a quality control measure. This study has presumed an initial population of devices with constant failure rates, and has focussed on the composition of the population of survivors after a period of service or burn-in.

The principal results have been a strong technical interpretation of how the "fittest" items survive. These results contain some previously known properties of such mixtures.

Recent work has been concerned with the effect of improving the initial population mixture on the mixture to be found in the populations of survivors. A kind of improvement that does persist has been found. Others prove to be surprisingly transient.

Publications:

J. D. Esary and H. Ziehms, "Reliability Analysis for Phased Missions." Edited by R. E. Barlow, J. B. Fussell, and N. D. Singpurwalla, published by the Society for Industrial and Applied Mathematics, 1975.

H. Ziehms, "Approximations to the Reliability of Phased Missions," Technical Report, NPS55Ey75091, September 1975.

M. G. Bell, "Multi-Phase-Mission Reliability of Maintained Standby Systems," Technical Report NPS55Ey75121, December 1975.

Thesis Directed:

M. G. Bell, "Multi-Phase-Mission Reliability of Maintained Systems," Doctoral Dissertation, December 1975.

Title: Naval Effectiveness and Vulnerability Studies

Investigators: R. N. Forrest, J. D. Esary, B. O. Shubert, R. H. Shudde, and A. R. Washburn, Professors of Operations Research

Sponsor: Department of the Navy

Objective: To develop and improve specific Navy effectiveness and vulnerability models.

Summary: This work dealt with the following subjects: Phased Mission Reliability: In a phased mission, the relevant system configuration changes during consecutive time periods (phases). Several important Navy systems are required to perform phased missions for which reliability considerations are significant. Search Detection and Localization Modeling: Work was done on the problem of analytically modeling submarine search detection, and localization. Attention was given to non-acoustic sensors.

Publications:

B. O. Shubert, "Modeling a Random Search", Technical Report NPS 55SY 75071, July 1975.

R. N. Forrest, "A Submarine Magnetic Anomaly Signal Model with Programs for A Hewlett-Packard 65 Calculator", Technical Report NPS 55Fo 75101, October 1975.

M. G. Bell, "Multi-Phase-Mission Reliability of Maintained Standby Systems", Technical Report NPS 55EY 75121, December 1975.

R. H. Shudde, "Nonsymmetric Ballistic Range, Height, Time-of-Flight and Optimal Flight Path Angle Computations with Programs for a Hewlett-Packard 65 Calculator",Technical Report NPS 55Su 76031, March 1976.

Title: Magnetic Anomaly Detection Studies

Investigators: R. N. Forrest, Associate Professor of Operations Research and G. L. Sackman, Associate Professor of Electrical Engineering

Sponsor: Naval Air Development Center

Objective: To analyze and model magnetic noise and magnetic anomaly detection and localization systems.

Summary: This work dealt with the following subjects:

Geologic Magnetic Noise: Space-dependent geologic magnetic noise sources contribute to the magnetic noise background of magnetic anomaly detection and localization systems. A geologic magnetic noise model has been constructed for use in the development and evaluation of automatic signal detection algorithms. Experimental validation of the model is currently underway.

Magnetic Anomaly Detection Models: An evaluation of proposed magnetic anomaly detection systems can be based in part on magnetic anomaly detection models. A detection model which describes a magnetometer detection system has been developed for this purpose. A model which describes a gradiometer system is to be developed.

Publications: R. N. Forrest, "A Magnetic Anomaly Signal Model with Programs for a Texas Instruments SR-52 Calculator, Technical Report NPS 55Fo76021, February 1976.

Theses Directed: W. F. Burdick and J. J. Sheridan, "Modeling Geologic Noise for MAD Applications,"Master's Thesis, March 1976.

J. L. Harford and P. L. Reed, "A Comparison of the Signals Received by a Magnetometer Mounted on an Aircraft Flying Circular Patterns Versus Straight Line Paths," Master's Thesis, March 1976.

D. A. Pignotti and T. P. Winters, "A Feasibility Study for a Magnetic Anomaly Detection (MAD) Test Range," Master's Thesis, March 1976.

Title: Sensitivity of Gordon and Newell, and Buzen Models of Computer Configurations

Investigator: D. P. Gaver, Professor of Operations Research

Sponsor: Defense Communications Agency

Objective: To test the sensitivity of the GNB model of computer operation by comparison to a new model with different properties.

Summary: A probability model has been developed to describe the flow of programs of two types through a multiprogramming computer (CPU and peripherals). The model is solved numerically, using a variation of the Gauss-Seidel iteration technique. A program that carries out this program, and computer system measures of effectiveness (system element utilizations, queue lengths) has been written and submitted to the sponsor.

Conference Presentations: D. P. Gaver, "Sensitivity of Gordon and Newell, and Buzen Models of Computer Configurations," presented, by invitation, at the International Symposium on Computer Performance Modeling, Measurement, and Evaluation, Harvard University, March 1976.

Title: Stochastic Systems Analysis and Modelling

Investigator: D. P. Gaver, Professor of Operations Research

Sponsor: National Science Foundation

Objective: To develop realistic stochastic (probability) modelling techniques that are capable of yielding numerical results in a variety of applied areas.

Summary: Several models have been developed, using a diffusion approximation technique, communications systems, time-shared computing systems, maintenance and repair systems, and pharmacokinetic (compartment) systems. Papers have been prepared, and are in the process of being published.

Publications:

D.P. Gaver, "Probability Models in Logistics," Chap. 12 of Modern Trends in Logistics Research. Proc. of a conference sponsored by ONR, ed. by W. H. Marlow, published by MIT Press, 1976.

D.P. Gaver and G. Humfeld, "Multitype Multiprogramming: Probability Models and Numerical Procedures." Proc. of the Int. Symp. on Computer Performance Modelling, Measurement, and Evaluation; Harvard University, Cambridge, Mass., March 1976.

Title: Global Optimization of Nonlinear Programming Problems

Investigator: J. K. Hartman, Associate Professor, Operations Research Department

Sponsor: Foundation Research Program (6.1)

Objective: To continue investigation of a class of linear approximating problems for nonconvex nonlinear programs.

Summary: In previous work the "Grid Linearization" algorithm for nonlinear optimization was extended to apply to separable nonconvex nonlinear programming problems.

Current research has focused on the properties of the method when roundoff errors are present in the computations and has resulted in an approximate optimality theorem in these circumstances.

A related effort has formally extended the method to nonseparable nonconvex problems. Although the mathematics of the nonseparable case is straightforward, it is believed that the method would be very difficult to use computationally.

Publications:

J. K. Hartman, "Extension of the Grid Linearization Algorithm for Convex Optimization to Nonconvex Nonlinear Programs," Technical Report NPS55Hh75071, July 1975.

J. K. Hartman, "Epsilon Optimality for a Global Optimization Algorithm," Technical Report NPS55Hh75121, December 1975.

J. K. Hartman, "A Branch & Bound Method for Nonseparable Nonconvex Optimization," Technical Report NPS55Hh75102, October 1975.

Title: Ridge Regression

Investigator: H. J. Larson, Professor, Operations Research Department

Sponsor: Foundation Research Program (6.1)

Objective: To review the current literature and examine the distribution of the ridge regression estimator over repeated samples.

Summary: Ridge regression is a subjective biased estimation technique whidh seems to give more sensible numerical estimates of unknown regression parameters than does ordinary least squares, in certain circumstances. A study was made of the variations on ridge regression described in the literature, and their applications. Some properties of an iterative Bayesian ridge regression estimation technique were derived. Several procedures for getting the distribution of the ridge estimator, over repeated samples, were investigated. None of these leads to simple methods of comparing the classical properties of ordinary least squares estimators with those of ridge estimators.

Publications: None

Theses Directed:

E. B. Lewis, "An Investigation of the Probability Distribution of the Ridge Regression Estimator for Linear Models," Master's Thesis, March 1976.

Title: Manpower Planning and Budgeting Models

Investigator: K. T. Marshall, Professor of Operations Research

Sponsor: Headquarters Marine Corps and Navy Personnel Research and Development Center

Objective: To continue previous studies in manpower policy planning with emphasis on on-line interactive computer models.

Summary: Two areas were emphasized, a) enlisted force year-end strength planning and forecasting under alternative recruitment policies and budget constraints, and b) officer force structure planning, with determination of promotion policies and budget requirements. The theory of manpower modelling progressed simultaneously and is published in the following reports. A book, entitled "Manpower Planning Models," is to appear in January 1977.

Publications:

K. T. Marshall and R. C. Grinold, "Manpower Planning Models - III, Longitudinal Models," Technical Report NPS55Mt75081, August 1975.

K. T. Marshall and R. C. Grinold, "Manpower Planning Models - IV, Snythesis of Cross-sectional and Longitudinal Models," Technical Report NPS55Mt75111, November 1975.

K. T. Marshall and R. C. Grinold, "Manpower Planning Models - V, Optimization Models," Technical Report NPS55Mt75101, October 1975.

Title: CNET Efficiency Indicators

Investigator: K. T. Marshall, Professor of Operations Research

Sponsor: Chief of Naval Education and Training

Objective: To investigate and develop certain indicators of education and training efficiency for use by CNET staff for internal management.

Summary: The use of economic-type indicators, such as the Laspoyeres, Paasch and Fisher Indices, by CNET for internal monitoring of their education and training operations was investigated. Their use was demonstrated using data from SSC San Diego. It is expected that these preliminary studies will be continued.

Publications: None

Title: Analysis of Discrete Time Resource Allocation Policies with Applications to Budgeting

Investigators: K. T. Marshall, Professor, and F. R. Richards, Associate Professor, Operations Research

Sponsor: Foundation Research Program (6.1)

Objective: To analyze the stochastic properties of the sequence of deficits produced over time with various budgeting policies which lead to correlated supplies and demands. Such policies are commonly observed in government budgeting procedures.

Summary: A set of policies in which current and future budgets are determined as convex linear combinations of past demands was postulated, and the properties of the resulting deficits and surpluses were determined. The sequence of deficits was shown to be related to the sequence of waiting times in a single-channel queue. However, the usual assumptions of independence made for queueing systems are unrealistic in the context of many resource allocation problems. Our results show that certain strongly correlated systems can be analyzed. Our results have applications in correlated queueing systems as well as a wide variety of resource allocation problems.

Publications: K. T. Marshall and F. R. Richards, "Analysis of Deficits in Discrete Time Resource Allocation Problems with Correlated Supplies and Demands," Technical Report NPS55MtRh76051, May 1976.

Conference Presentations: K. T. Marshall, "Analysis of Deficits and Surpluses Under Various Budgeting Policies with Relation to Queueing and Scheduling Problems," presented to Operations Research Seminar Series at Bell Telephone Laboratories, Holmdel, New Jersey, March 1976.

Title: Analysis of Mobility, Agility and Survivability in the Land of Combat Environment

Investigator: Samuel H. Parry, Assistant Professor of Operations Research

Sponsor: U. S. Army Armor and Engineer Board

Objective: To assist in the experimental design and analysis of the S-Tank Agility/Survivability Test conducted at Fort Knox in 1975-76. To determine the relationship between apparent target motion parameters and gunner performance variables. This is a continuing project leading into the High Mobility/Agility Vehicle Test scheduled for 1977.

Summary: One of the most important questions being posed by the Armor community today is "What is the effect of mobility and agility on tank survivability on the battlefield?" The overall goal of this continuing research is to formulate a viable quantification of mobility and agility that can be directly related to induced tracking errors (and hence to probability of hit).

The data base for this research consists of approximately 1500 trials utilizing four fire vehicles, seven target vehicles, three courses, five maneuvers, and two test sites. At this time, data reduction has been accomplished for approximately 300 trials. The investigator formulated a split plot design for conducting analysis of variance (reference 1 under Publications). Programs were developed to determine apparent target motion profiles for each trial in a variety of modes (references 1, 2, 3). Several statistical techniques, such as partial correlation, canonical correlation, factor analysis, and multiple regression are being employed to determine the relationship between gunner errors and target motion parameters. Preliminary analysis indicates that significant positive correlation exists between apparent velocity and tracking errors. The relationships between apparent acceleration, aspect rate of change, and tracking performance are unclear at this time.

It is anticipated that data analysis from the STAGS Test will be completed by November 1976. These results will be instrumental in the design of the subsequent High Mobility/Agility Test to be conducted in 1977.

Publications:

Parry, Samuel H., "Studies of Mobility, Agility, and Survivability in the Land Combat Environment," Technical Report NPS-55Py75091, September 1975.

Parry, Samuel H., "Land Combat Studies, Task Order No. 76-148," Battelle Columbus Labs, Durham, N. C., December 1975.

Parry, Samuel H., "The Effects of Apparent Target Motion of Battlefield Survivability, Task Order No. 76-0059," Battelle Columbus Labs, Durham, N. C., June 1976.

Title: An Investigation of the Causes of Increased Major Aircraft Accidents in Specific Months

Investigator: G. K. Poock, Associate Professor of Operations Research

Sponsor: Naval Safety Center

Objective: To identify reasons, if any, for high major aircraft accident rates in some months of the year versus other months.

Summary: In FY 76, the main effort was devoted to analysis of data by specific command and by specific type of aircraft. There appear to be no specified trends in either commands or aircraft types.

Publications:

G. K. Poock, "Trends in Major Aircraft Accident Rates," Technical Report NPS 55PK76061, June 1976.

G. K. Poock, "Factors Involved in the Variability of Monthly Major Aircraft Accident Rates," Technical Report NPS 55PK76071, July 1976.

Theses Directed:

J. S. Maxwell and L. V. Stucki, "Analysis of the Variable Behavior Manifested in all Navy/Marine Major Aircraft Accident Rates," Master's Thesis, September 1975.

G. F. Johnson, "Analysis of U.S. Navy Major Aircraft Accident Rates by Aircraft Type," Master's Thesis, September 1976.

L. C. Bucher, "Analysis of U.S. Navy Aircraft Accident Rates in Major Aviation Commands," Master's Thesis, September 1976.

Title: Conceptual Analysis Program

Investigators: M. G. Sovereign, D. R. Whipple and M. K. Block, Associate Professors of Operations Research and Administrative Sciences

Sponsor: Chief of Naval Operations

Objective: To introduce faculty members to CNO level problems and provide conceptual approaches to analysis of these problems.

Summary: This year the program's major effort was continuation of the previous year's work on the study of the military health care system. In particular, data was analyzed to determine the factors which determine the supply of physicians to the military. This work was done by Professors Whipple and Block. A smaller effort on costing was undertaken by Professor Sovereign.

Publications: M. G. Sovereign, "A Conceptual Model for Setting Design-to-Cost Goals." Proceedings of the 37th MORS, July 1976.

Title: Optimal Fire-Support Strategies

Investigator: J. G. Taylor, Associate Professor of Operations Research

Sponsor: Office of Naval Research

Objective: To develop methodology for determining the optimal time-sequential fire-support allocation policy in several situations of tactical interest and to examine its dependence on such factors as the model of combat dynamics, quantification of combatant objectives, and battle termination conditions (i.e. unit breakpoints). Attention to be also given to modelling the combat attrition process and extracting information from such models (e.g. solving the associated Lanchester-Type equations for warfare).

Summary: The reporting of previously obtained results on optimal fire-support strategies was completed. In this previous work, deterministic optimal control theory was used to study the structure of optimal fire-support policies for some time-sequential tactical allocation problems with combat described by Lanchester-type equations of warfare. Numerous specific problems for determining optimal time-sequential fire-distribution policies for supporting weapon systems were studied. A sequence of the one-sided time-sequential tactical allocation problems was examined to study how the optimal fire-support policy depends on the nature of the combat model (in particular, maneuver element interactions). The modelling of the suppressive effects of supporting weapons and their inclusion in such allocation optimization problems were considered briefly. The dependence of the structure of optimal time-sequential fire-support policies on the quantification of military objectives was examined. The splitting of supporting fires between enemy units in an optimal policy was shown to depend on whether the objective is to attain an "overall" military advantage or a "local" advantage.

Additionally, some new work was done on obtaining insights into the dynamics of combat between two homogeneous forces modelled by Lanchester-type equations of modern warfare with time-dependent attrition-rate coefficients. It was shown that much new information about such models could be obtained by considering Liouville's normal form for X and Y force-level equations. New victory-prediction conditions that allow one to forecast the battle's outcome without explicitly solving the deterministic combat equations and computing

force-level trajectories were developed for fixed-force-ratio-breakpoint battles. These particular victory-prediction conditions involve only the initial force ratio and simple algebraic functions of the attrition-rate coefficients and their derivatives, whereas other such results of the author have involved higher transcendental functions. An important new canonical set of functions for solving Lanchester-type equations of modern warfare for combat between two homogeneous forces with power attrition-rate coefficients with "no offset" was developed. Tabulations of these functions, which we call Lanchester-Clifford-Schläfli functions, allow one to study this particular variable-coefficient combat model almost as easily and thoroughly as Lanchester's classic constant-coefficient one.

Publications: J. G. Taylor, "Optimal Fire-Support Strategies," Technical Report NPS 55 Tw 76021, February 1976.

Title: Study of Variable-Coefficient Lanchester-Type Equations of Warfare

Investigator: J. G. Taylor, Associate Professor, Operations Research Department

Sponsor: Foundation Research Program (6.1)

Objective: To extend the state-of-the-art for developing and analyzing solutions to Lanchester-type equations of warfare in order to develop insights into the dynamics of combat (by explicitly showing the dependence of combatant force levels on the physical parameters of the combat attrition process and on initial conditions) and also in order to facilitate sensitivity and other parametric analyses. In particular, a specific objective is to develop techniques for predicting the outcome (e.g., force annihilation) in variable-coefficient Lanchester-type combat from initial conditions *without explicitly solving the attrition* equations.

Summary: A mathematical theory was developed for predicting force annihilation from initial conditions without having to explicitly compute force-level trajectories for Lanchester-type equations of modern warfare for combat between two homogeneous forces with temporal variations in fire effectivenesses. It was shown that prediction of force annihilation involves a single parity-condition parameter, which depends on only the model's attrition-rate coefficients. A canonical auxiliary parity-condition problem was introduced for determining this parity-condition parameter. Further research was performed on constructing the solution to variable-coefficient Lanchester-type equations of modern warfare from so-called hyperbolic-like general Lanchester functions. The force-annihilation results provided further information about the mathematical properties of these Lanchester functions. Important new results were obtained on how the parity-condition parameter depends on the intensity of combat and the relative fire effectiveness of the combatants. Approximate solutions were also examined, and new error bounds were developed for the Liouville-Green approximation to initial-value problems.

This research also developed new "simple" victory-prediction conditions for two Lanchester-type models, one linear and the other nonlinear, of combat between two homogeneous forces with superimposed effects of supporting weapons not subject to attrition. These simple victory-prediction conditions involve only the initial conditions of battle and certain assumptions about the nature of temporal variations in the attrition-rate coefficients. They were developed for fixed-force-ratio-breakpoint battles by studying the force-ratio equation for the linear combat model. The inadequacy of previous victory-prediction results was explained by examining (for the linear combat model without the supporting fires) new "exact" victory-prediction conditions, which show that even the range of possible battle outcomes may be significantly different for variable-coefficient and constant-coefficient models.

Previous results on the optimal allocation of military resources to battle and associated optimization theory were revised for publication. For example, the committing of forces to battle was examined as a mathematical programming problem. It was shown that one can determine whether or not it is "beneficial" for the victor to initially commit his entire force by considering the instantaneous force-change ratio for Lanchester-type combat equations.

Publications: J. G. Taylor and C. Comstock, "Force-Annihilation Conditions for Variable-Coefficient Lanchester-Type Equations of Modern Warfare, I: Mathematical Theory," Technical Report NPS55Tw76081, August 1976.

Conference Presentations:

G. G. Brown and J. G. Taylor, "An Examination of the Effects of the Criterion Functional on Optimal Fire-Support Policies," Operations Research Society of America and The Institute of Management Sciences (ORSA/TIMS) Joint National Meeting, Las Vegas, Nevada, November 1975.

G. G. Brown and J. G. Taylor, "Canonical Methods in the Solution of Variable-Coefficient Lanchester-Type Equations of Modern Warfare," ORSA/TIMS Joint National Meeting, Las Vegas, Nevada, November 1975.

J. G. Taylor, "On the Relationship Between the Force Ratio and the Instantaneous Casualty-Exchange Ratio for Some Lanchester-Type Models of Warfare," ORSA/TIMS Joint National Meeting, Philadelphia, PA, April 1976.

Theses Directed:

J. Craig, "The Effect of Uncertainty on Lanchester-Type Equations of Combat," Master's Thesis, 1975.

B. G. Baskerville, "The Significant Parameters Affecting the Modeling of Target Acquisition of Ground Combat Targets from Tactical Helicopters," Master's Thesis, 1976.

D. W. Brewer, "A Parametric Analysis of the Dismounted Final Assault," Master's Thesis, 1976.

J. N. Carpenter, "A Numerical Evaluation of the Liouville-Green Approximation of Variable-Coefficient Lanchester-Type Equations of Modern Warfare," Master's Thesis, 1976.

Y. Lee and Y. Pi, "The Estimation of Lanchester Attrition-Rate Coefficients for an Aggregated Combat Model," Master's Thesis, 1976.

R. A. Martray, "Development of an Aggregated Lanchester-Type Combat Model for the Evaluation of Air-War Allocation Strategies in a Theater Sector," Master's Thesis, 1976.

Title: Cost Effectiveness Considerations for Navy Harbor Spill Removal/Recovery Program

Investigators: Marlin Thomas, Associate Professor of Operations Research, Alan McMasters, Associate Professor of Administrative Sciences

Sponsor: Naval Facilities Engineering Command

Objective: To review the operations engineering considerations and to assist NAVFAC in the technical evaluation phase for the Harbor Oil Spill Removal/Recovery System Development Program. This is a continuing project.

Summary: A working conference on cost effectiveness of harbor oil spill removal/recovery systems was held at the Naval Postgraduate School on 3 and 4 November 1975. Specifically addressed were the defining of expected mission profiles for systems operational scenarios for the technical evaluation occurring in March, 1976, and performance capabilities and environmental goals, and the identifying of alternative systems.

A cost effectiveness analysis was conducted on oil containment boom which made use of life cycle performance data obtained from approximately twenty Naval facilities. This data allowed estimates to be made on equipment useful lifetime as a function of the levels of maintenance costs and oil spill business. A report to the sponsor is being prepared.

Publications: None

Title: On Search for a Diffusing Target

Investigator: Alan R. Washburn, Associate Professor of Operations Research

Sponsor: Department of the Navy

Objective: To provide quidelines for the distribution of search effort when the target being sought is itself moving.

Summary: It is known that a modification of the heat equation describes the density function of the position of a target moving about randomly. By employing the adjoint equation, a necessary condition for a search to be optimal is found, as well as a computational technique for finding a locally optimal search plan.

Publications: None

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

The Department of National Security Affairs has expanded the research program during the past 1976 Academic Year in sponsored and unsponsored programs. These programs are directed to research investigations concerning national and international security affairs, strategic planning, and naval intelligence. Some of the research projects underway provide the foundation for additional research by individual students with thesis requirements.

Among the categories of competence and interest, investigations are pursued in the following general areas: U. S. national security interests and problems in the Middle East, Soviet Union, Western Europe, or Asia; military escalation in international conflict; politico/military decision-making; methodology for forecasting technological threat; military balances, and measuring perceptions about them; data analysis in national security policymaking; the presidency and national security; and the course of U.S. decisions.

It is noteworthy that the majority of both sponsored and unsponsored projects result in publication. Project sponsors include the Naval Intelligence Command, the Technology Assessment Office, OSD, OJCS, Plans and Policy Division, Naval Intelligence Support Center, U. S. Army, Ballistic Research Laboratory, Office of Defense Research and Engineering, and the Hoover Institution on War, Revolution, and Peace. The national stature of project sponsors, the technical research expertise of faculty, and published documentation of completed projects are indicative of the continuing expansion in research endeavors in the Department of National Security Affairs.

Title: The October War: A Study in the Politics of Escalation

Investigator: John W. Amos, II, Assistant Professor of National Security Affairs

Sponsor: Naval Intelligence Command

Objective: To analyze the factors correlated with military escalation in the Arab/Israeli conflict.

Summary: Revised version of the original study prepared for NAVINTCOM. A comparison of the factors leading to the 1967 and 1973 Wars; and analysis of Arab strategy, training, and tactical doctrines; a summary of factors effecting Arab politico/military decision-making. Draws extensively on Arab world sources. Includes a series of escalation scenarios. (377 pages & appendix).

Publications: None

Title: The Middle East: The Problem of Quarantine

Investigator: John W. Amos, II, Assistant Professor of National Security Affairs

Sponsor: None

Objective: Analysis of U.S. national security interests and problems in the Middle East.

Summary: Statement of U.S. interests in the Middle East; summary of the problems involved in securing these interests; examination of several alternative strategies available to U.S. policy-makers. Analysis is set against the background of post-1973 changes within the Arab world, and in the relative positions of the U.S. and U.S.S.R. in the area.

Publication: J. W. Amos, "Foreign Policy and U.S. National Security: Major Post-Election Issues," Published as a chapter in: William W. Whitson, ed., Praeger Publishers, Inc., 1976.

Title: The United States and the Philippines

Investigator: Claude A. Buss, Professor of National Security Affairs

Sponsor: The Hoover Institution and the American Enterprise Institute for Public Policy

Objectives: To study the background of United States - Philippine relations; to state clearly the respective perceptions of national interests and policies; to analyze current problems between the two nations; and to present alternatives for future action; with conclusions, and recommendations as appropriate.

Summary: This research has been completed and is in the hands of the publishers. It is a part of a long-term and continuing study of the position of the United States in the Western Pacific and East Asia after the conclusion of the Vietnam affair. Results obtained will be published in forthcoming book to be brought forth by the sponsors. It will be most useful in the analysis and description of the problems and in presenting the diplomatic record in a readily accessible form. It endeavors to explain the objectives of the two countries in their foreign relations, and in so doing exposes the roots of conflict. Separate sections deal with security arrangements including the bases and military assistance and with economic relations after the expiration of the Laurel-Langley agreement in 1974. Due attention is given to the influence of the martial law situation and the temporary denial of civil rights on the traditional good relations between the United States and the Philippines. This research involved study trips to Washington and to the Philippines, the better to judge the respective role of the two in the evolving balance of powers in the Pacific.

Publications: None

Title: The 1974 Soviet Merchant Marine

Investigator: D. C. Daniel, Assistant Professor of National Security Affairs

Sponsor: None

Objectives: (1) To document the size, growth, and major characteristics of the Soviet merchant fleet.

(2) To compare its size, growth, and characteristics with those of the world merchant fleet as a whole.

(3) To highlight 1974 ship construction, fleet operation, and port development trends.

Summary: Conclusions as to size, growth, and inventory characteristics of both the Soviet and world fleets were based on data aggregated by this writer from Lloyd's Register of Shipping, Western shipping journals and Soviet sources provided additional necessary information to meet the objectives laid out above.

Among some of the major conclusions are that the Soviet Merchant Marine is one of the world's largest; it is continuing to grow; it differs significantly from the world fleet in many ways though it is tending closer toward world "norms" in many areas. The Soviets are conscious of the need to improve their port facilities and eliminate port-associated problems which restrict the efficiency of their fleet. They continue to use their fleet as an auxiliary arm of their military system.

Publication: D. C. Daniel, "The 1974 Soviet Merchant Marine," published in D. R. Jones, Ed. The Soviet Military Affairs Review, Academic International Press, 1977.

Title: French Perceptions of U.S. - Soviet Military Balances as Revealed in Défense Nationale.

Investigator: D. C. Daniel, Assistant Professor of National Security Affairs

Sponsor: Advanced Research Project Agency

Objectives: In conjunction with ARPA Order 3117, I am coding twenty years (1955-1974) of selected articles and and chronical items from the French journal Défense Nationale. At the focus of inquiry are balance comparisons made by the authors of the journal relative to U.S. - Soviet and certain East-West military capabilities. I am seeking to answer the following questions:

(1) What are the perceptions of the authors as to which side is ahead in the balance comparisons?

(2) What reasons do they give for justifying their views?

(3) What sources do they mention as providing them information for reaching their conclusions?

(4) What events do they acknowledge as triggering their thinking on a particular balance?

(5) What do they say should be done in light of the state of a particular balance as they percieve it?

(6) Which balances most/least frequently provided the basis for comparisons.

Summary: This study applies a quantitative technique (content analysis) to coding the journals in order to ascertain trends. The study is still in progress, and final results will be available 1 October 1976.

Publications: D. C. Daniel, "Défense Nationale Perceptions of the U. S.-Soviet Military Balances," Technical Report 56D176111, November 1976.

Title: The U.S. Navy in the Indian Ocean: The Surface Ship Naval Presence Issue

Investigator: D. C. Daniel, Assistant Professor of National Security Affairs

Sponsor: None

Objective: To evaluate various arguments for and against increasing the U.S. naval surface ship presence in the Indian Ocean.

Summary: The arguments were grouped into three major schools of thought as to what U.S. policy should be. These recommendations and their rationale were compared and contrasted. The study ended with this writer making his own recommendations based upon his analysis and evaluation of the differing rationale.

Publication: D. C. Daniel, "South Asia: The Problem of Secure Lines of Communication," published in W. W. Whitson, Ed. Foreign Policy and National Security, Praeger (Special Studies Series), 1976.

Title: The President and National Security, Vol. II

Investigator: Stephen Jurika, Adjunct Professor of National Security Affairs

Sponsor: None

Objective: Prepare, with co-author Malcolm Smith, volume two of The President and National Security. (Volume one was published by Kendall/Hunt, Dubuque, Iowa in 1972.

Summary: The two volumes document the records of American presidents from Washington to Nixon with respect to "national security" in its many facets. More especially, it is seldom that both the "how" and the "why" of decision-making is released to the public, including much that is new from sources that have been classified over the years.

The thesis of both books is that so long as American elections are scheduled AND HELD no President can gather into his hands the absolute power that so tends to corrupt. Since Volume one, the Watergate affair and the limitations on presidential power corroborate our thesis.

Publications: None

Title: Arthur W. Radford, Admiral of the Skies

Investigator: Stephen Jurika, Adjunct Professor of National Security Affairs

Sponsor: The Hoover Institution on War, Revolution, and Peace

Objective: To continue in the Hoover Institution tradition of publishing scholarly books.

Summary: The papers of Admiral Arthur W. Radford are now in the possession of the Hoover Institution. The Publications Committee of the Hoover Institute selected me to:

a. Select, arrange, and annotate the 1493 pages of typed manuscript, select and obtain photographs, charts, tables, and maps.

b. Write and edit some 500 pages (printed) of final manuscript to be published as a hardcover book.

c. Provide many other services which need not be noted.

Admiral Radford was one of the most important naval aviators in the history of the United States Navy. He was present at numerous high-level meetings and conferences as an advisor to James Forrestall, Presidents Truman and Eisenhower, and was Chairman of the Joint Chiefs of Staff for seven years. During those cold war years, his impact on the course of U. S. decisions was immense, and the Admiral was meticulous and clear at writing down notes and memoranda, in addition to a daily journal. From the material in the Hoover archives, and from the Admiral's sharp observations, there flow new light and perspectives--even major differences, between his well documented records and the published memoirs of two Presidents and a host of major officials such as Dean Acheson.

Publications: None

Title: Data Analysis in National Security Policymaking

Investigator: E. J. Laurance, Assistant Professor of National Security Affairs, R. G. Sherwin, Assistant Professor (Research Associate) of National Security Affairs

Sponsor: Office of the Joint Chief of Staff, Plans and Policy Division

Objective: For 1975 - 76, the objective of this project has been to devise a data-based scheme for researching and monitoring international transfers of conventional arms. The project has also been concerned with linking conventional wisdom about arms transfers with other international relations phenomena such as political interaction, recent conflicts, trade, alignment, and the flow of strategic commodities, and so forth.

Summary: The conclusion reached after the first phase of the project is that statistical analysis of arms transfer data is difficult due to a paucity of cases, the measurement problem, and the inadequate distribution and organization of relevant data. Significant progress was made in the development of a valid measure of the arms transfer concept through the application of multiple attribute utility theory.

Conference Presentations: Laurance, Edward J., "Arms Transfers and Influence in Latin America." Presented to International Studies Association, February 1976.

Sherwin, Ronald G., "International Commitments and Arms Transfers: A Conceptual Discussion." Presented to the International Studies Association, March 1976.

Laurance, Edward J., "The Changing Nature of Conventional Arms Transfers: Implications for U.S. National Security Planning and Policy Research." Presented to the 1976 Senior Conference, U.S. Military Academy, May 1976, West Point, New York.

Laurance, Edward J., and Sherwin, Ronald G., "Understanding Arms Transfers Through Data Analysis." Conference on the Implications of the Military Build-Up in Non-Industrial States. Fletcher School of Law and Diplomacy, May 1976.

Thesis Directed: Le Grow, Allan Wesley, "Measuring Aircraft Capability for Military and Political Analysis," Master's Thesis, March 1976.

Title: A General Methodology for Forecasting the Technological Threat from the Soviet Navy

Investigator: R. H. S. Stolfi, Associate Professor of National Security Affairs

Sponsor: Office of Naval Research and Naval Intelligence Support Center

Objective: The investigator working as part of a team with Associate Professor Peter C. C. Wang, Department of Mathematics, was tasked to develop a methodology for forecasting the technological threat from the Soviet Navy.

Summary: A technological threat forecasting methodology was developed, which has been tested by naval intelligence students at the Naval Postgraduate School and a group of analysts from NISC, and has proven to be realistic and capable of useful, practical application. The methodology is presently being expanded to include application to weapons platforms (as distinguished from weapons) and application to other navies of the Eurasian Communist Countries.

Fourteen class projects are being edited and modified to appear as either Naval Postgraduate School research reports or research memoranda from the recently proposed Naval Postgraduate School Center for Research in Intelligence. Each project consists of an actual forecast of a particular category of weapons comprising a ten-page executive summary, systematically arranged forecast, and various appendices.

Publications: None

Title: Weapons Threat to the United States from the Armed Forces of the Eurasian Communist Countries (ECC)

Investigator: R. H. S. Stolfi, Associate Professor of National Security Affairs

Sponsor: U. S. Army, Ballistic Research Laboratory (BRL)

Objective: In 1973, the Department of Defense under the earlier insistance and guidance of John Foster, published the eight-volume work representing the state of weapons technology in the United States entitled, "Weapons Technology Coordinating Paper." At that time, I had been responsible for presenting the ECC Technological Threat, Volumes I - VII, and putting together the general picture of the threat in Volume VIII. The BRL, as executive agent for DOD in keeping the work current, gave me the task in January 1976, to edit and update Volumes I - VII from the viewpoint of the weapons threat from the Eurasian Communist Countries.

Summary: From January - August 1976, the eight volumes of the Weapons Technology Coordinating Paper were (1) edited for clarity and (2) changed substantively where necessary to reflect the latest information and intelligence.

Publications: R. H. S. Stolfi, "Weapons Technology Coordinating Paper," Eight Volumes, Office of the Director of Defense Research and Engineering, Washington, D. C., October 1976.

Title: Gun Systems Aquisition in the United States

Investigator: R. H. S. Stolfi, Associate Professor of National Security Affairs

Sponsor: Director of Defense Research and Engineering

Objective: Under the prompting of the Secretary of Defense (James Schlesinger) late in 1974, the Director of Defense Research and Engineering (Dr. Malcom Currie) brought together under the Defense Science Board, a special panel to examine the process of gun systems acquisition in the United States and to advise DDR&E and the Secretary of Defense on the state of the process and the means by which it could be improved. I served as primary consultant to the panel, attended most of its meetings, and accomplished various gun systems historical and technical research in support of its members.

Summary: The Panel published a two-volume report in which the principal finding was that the process for acquiring advanced gun systems in the United States has ground virtually to a halt. The report elaborates that the management system executing the process of gun systems acquisition has provided neither an overall sense of direction, clear incentives, nor adequate stimuli to affect the process.

Publications: R. H. S. Stolfi, "Report of the Task Force on Gun System Acquisition," Defense Science Board, Office of the Director of Defense Research and Engineering, Washington, D. C. Two Volumes, 1 August 1975.

DEPARTMENT OF PHYSICS AND CHEMISTRY

The research program in the Department of Physics and Chemistry has continued along several main lines: (1) Acoustics and Fluid Dynamics, (2) Atmospheric Optics, (3) Laser and Plasma Physics, (4) Atomic Physics, (5) Nuclear Physics, (6) Physical Chemistry, and (7) Solid State and Surface Physics. Under these headings, there are a number of related investigations being pursued by various faculty members as described below.

ACOUSTICS AND FLUID DYNAMICS

Influence of the upper ocean fluctuations on the propagation of sound by H. Medwin; Processing of ocean acoustic signals in response to the ocean fluctuations by H. Medwin; High intensity acoustic phenomena by A. Coppens and J. V. Sanders; Drag and noise reduction of underwater vehicles by J. V. Sanders and K. E. Woehler; Underwater acoustic range studies involving O. B. Wilson, J. V. Sanders, H. Dahl, A. Coppens; (Sound propagation on wave guides with time varying rough surfaces)(shallow water Anti-Submarine Warfare (ASW)) by A. Coppens.

ATMOSPHERIC OPTICS

This activity has evolved to be one of the strongest in the department and is done in cooperation with the Meteorological Department: Study of the optical propagation in the marine boundary layer as a function of turbulence and aerosols/fog at militarily important atmospheric window wavelengths, by E. C. Crittenden, A. W. Cooper, E. Milne, W. Rodeback, S. H. Kalmbach, and R. Armstead; Development and Calibration of Diagnostic Tools and Field Studies of Atmospheric Turbulence in the Presence of Marine Fog, by G. E. Schacher and C. Fairall.

LASER AND PLASMA PHYSICS

In the Laser and Plasma Laboratory the dynamics of plasma production by impact of pulsed laser radiation on solid targets is investigated by F. Schrwirzke and A. Cooper, using neodymium glass and carbon dioxide lasers. Generation of spontaneous magnetic field, emission of x-rays and momentum transfer to the target are studied in detail. Laser development is carried out in conjunction with this program. Coherent Anti-Stokes Raman Scattering (CARS) as an analytical probe is under study by W. Tolles. A compilation of mostly classified data on effects of high energy laser irradiation of materials is made by J. R. Neighbours.

ATOMIC PHYSICS

Our spectroscopic data center's compilation of vacuum ultraviolet spectral lines in continuing, emphasizing at present rocket borne stellar spectroscopy, R. L. Kelly.

NUCLEAR PHYSICS

F. R. Buskirk, J. N. Dyer and R. Pitthan are continuing their investigations of giant multipole resonances in various nuclei by inelastic electron scattering at the LINAC.

PHYSICAL CHEMISTRY

Continuing investigation of the reaction kinetics and catalytic properties of palladium complexes by R. A. Reinhardt; thermodynamics of internal explosion processes by G. E. Kinney.

SOLID STATE AND SURFACE INTERACTION PHYSICS

Investigation by means of computer simulation of ion-surface interactions by D. E. Harrison, Jr.

Title: Measurement of Nuclear Giant Resonances by High Energy Electron Scattering

Investigators: F. R. Buskirk, E. B. Dally, J. N. Dyer and R. Pitthan, Professors, Physics and Chemistry Department

Sponsor: Foundation Research Program (6.1)

Objective: To investigate the collective modes of oscillation (giant resonances) of medium and heavy nuclei by means of inelastic electron scattering, using the electron linear accelerator (Linac) as the source of high energy electrons. Specific objectives include: (a) more positive identification of the monopole (breathing mode) resonance; (b) a systematic investigation of the isovector and isoscalar quadrupole resonances for nuclei ranging in mass from 58 to 238; and, (c) identification of the octupole mode.

Summary: The efforts have fallen into two broad categories, (a) Giant Resonance Research, and (b) Improvements in Spectrum Analysis.

(a) Giant resonance measurements were made in ^{89}Y at 90 MeV and scattering angles of 75°, 90°, 105° and 120°. Nine resonances were observed in a range of excitation energy from 6 to 38 MeV, and the results are listed in the thesis (9). One very important result of this experiment concerns the width of the isoscalar E2 resonance (14.86 MeV). In an early (1972) electron scattering experiment by the Sendai group (Japan) with the neighboring nucleus ^{90}Zr, a very large width of 4.8 MeV was found. This result was not surprising at the time, but subsequent experiments with many other nuclei in the ensuing years would make this result hard to understand. Our results indicate that the broad resonance actually consists of two resonances, M1 at 13.6 MeV and E2 at 14.9 MeV.

(b) The Radiation Tail refers to the continuous spectrum of electrons which accompanies inelastic electrons scattering, and in fact accounts for 90% or more of the electrons seen in a spectrum. To obtain a nuclear spectrum the radiation tail must be subtracted and knowledge of its energy dependence is essential. In the present spectrum analysis procedure, the observed spectrum is fit to adjustable resonances and a constant time the radiation tail function. The constant would be 1.0 only if the radiation tail function were known exactly, but the experimental values of the constant ranging from 0.9 to 1.1 indicate that the function is known more accurately than had been expected (2).

(c) Related research is described in the report on the NSF project.

Publications:

G. L. Moore, F. R. Buskirk, E. B. Dally, J. N. Dyer, X. K. Maruyama and R. Pitthan; "The Widths of the E2 (T = 0 and T = 1) Giant Resonances in ^{165}Ho," Zeit Schrift fur Naturforschung, 31a, 668 (1976).

R. Pitthan and F. Buskirk, "Line Structure and Resonant Structure in ^{208}Pb," Bulletin of the American Physical Society, 21, 516 (1976).

Theses Directed:

D. H. DuBois and G. M. Bates, "Electro-Excitation of Giant Resonances in ^{60}Ni Between 5 and 30 MeV Excitation Energy," Master's Thesis, June 1976.

J. O. Shannon and W. H. Smith, "Electro-Excitation of Giant Resonances Between 6.1 and 38 MeV Excitation Energy in ^{89}Y," Master's Thesis, June 1976.

E. F. Gordon, "An Investigation of the Natural Line Shape of the Giant Dipole Resonance," Master's Thesis, 1975.

Title: Electro-Excitation of the Collective Hydrodynamic Oscillation of Nuclei: The Giant Resonances

Investigators: F. R. Buskirk, E. B. Dally, J. N. Dyer and R. Pitthan, Professors of Physics and Chemistry

Sponsor: National Science Foundation

Objectives: The overall objective is the survey of giant resonances in medium and heavy nuclei, from mass 50 to 238. A specific objective has been the study of the isotope pair ^{58}Ni and ^{60}Ni, to see if the isospin splitting of the giant dipole resonance, measured by (γ,n), could be verified and to see if corresponding isospin effects occur for the isovector quadrupole resonance.

Summary: Experiments with Nickel isotopes have been done in the past, but many questions remain unanswered. The E1 resonance has been measured with (γ,n) and (γ,p) in both ^{58}Ni and ^{60}Ni. While ^{60}Ni fits in the systematic behavior of the E1 resonance, ^{58}Ni showed an abnormally large $(\gamma,p)/(\gamma,n)$ ratio, i.e. a very small percentage of the sum rule is exhausted by (γ,n). In contrast, our results, which show the total giant dipole resonance strength, and in ^{58}Ni it is significantly larger than in ^{60}Ni, which is difficult to understand.

Information concerning the isovector E2 resonance is generally scarce and most of the work reported so far has been done in our laboratory. One specific question, which may influence our concept of isospin very much, is the question if, and how, the $\Delta T = 1$ E2 resonance splits into T< and T> components. Direct comparison of the $T = 1$ nucleus ^{58}Ni with the $T = 2$ nucleus ^{60}Ni may offer the best possibility to learn about this effect. Our preliminary data indicate the possibility of such splitting, but more measurements are necessary.

Another surprising feature is a pair of E3 lines (or group of states) at 6.1 MeV and 7.0 MeV, which change their relative strength in going from ^{58}Ni to ^{60}Ni.

Knowledge of the energy dependence or shape of the giant resonance lines is needed when experimental spectra are fitted with several overlapping resonance forms, and a not exactly known background. To test line shape functions, (γ,n) spectra, which have little background ambiguity were fitted to various possible forms. It was found that the strength function was fit best by a Breit-Wigner resonance shape, and this result should aid in the analysis of our (e,e') spectra which involve many more resonances.

Related results for ^{89}Y and the radiation tail structure are described in the corresponding report for the NPS Foundation Research Program.

Publications:

G. L. Moore, F. R. Buskirk, E. B. Dally, J. N. Dyer, X. K. Maruyama and R. Pitthan: "The Widths of the E2 (T = 0 and T = 1) Giant Resonances in ^{165}Ho", Zeitschrift für Naturforschung, 31a, 608 (1976).

R. Pitthan and F. R. Buskirk: "Line Structure and Resonant Structure in ^{208}Pb", Bulletin of the American Physical Society, 21, 216 (1976).

Theses Directed:

E. F. Gordon: "An Investigation of the Natural Line Shape of the Giant Dipole Resonance", Master's Thesis, 1975.

D. H. DuBois and G. M. Bates: "Electro-Excitation of Giant Resonances in ^{60}Ni between 5 and 30 MeV Excitation Energy," Master's Thesis, June 1976.

J. O. Shannon and W. H. Smith: "Electro-Excitation of Giant Resonances Between 6.1 and 38 MeV Excitation Energy in ^{89}Y", Master's Thesis, June 1976.

Title: Laser Produced Plasmas

Investigators: A. W. Cooper and F. Schwirzke, Associate Professors, Physics and Chemistry Department

Sponsor: Foundation Research Program (6.1)

Objective: In this continuing project the interaction is investigated between intense laser pulses and targets. The dynamics of the laser produced plasma and self-generated magnetic fields are studied.

Summary: In the interaction of high-power pulsed laser radiation with a solid target, gas breakdown and subsequent plasma formation in the vicinity of the surface dominate the later transfer of energy and momentum to the solid. The interaction of 20-nsec 300-MW pulses of 1.06-μm laser radiation with aluminum targets in vacuum has been studied. The time history of the target impulse has been measured with a Sandia quartz gauge. A time sequence of plasma density maps constructed from floating double-probe data has been used with measured expansion velocities to estimate the plasma momentum. The results show that the stress wave is predominantly produced by about 10% of the evaporated target material which is ionized and expands from the surface in the form of a hot plasma during and shortly after the laser pulse. Initial measurements were also made of target impulse in layered materials (solar cell models) in air and vacuum environment using 5-10 J 250 μsec pulses from a CO_2 TEA laser.

Publications: A. W. M. Cooper, F. Schwirzke, and K. M. Brooks, Sr., "Time Development and Symmetry of a Laser-Produced Plasma Plume on a Plane Target," Bulletin of American Physical Society, 20, 1266 (1975). Presented by A. W. Cooper at the Annual Meeting of the Division of Plasma Physics of the American Physical Society, St. Petersburg, Florida, November 1975.

F. Schwirzke, A. W. M. Cooper and P. Krehl, "Correlated Measurements of Laser Induced Stress Waves and the Dynamics of the Laser Produced Plasma," Bulletin of the American Physical Society, 20, 1266 (1975). Presented by F. Schwirzke at the Annual Meeting of the Division of Plasma Physics of the American Physical Society, St. Petersburg, Florida, November 1975.

R. S. Case, Jr. and F. Schwirzke, "Background Gas Pressure Dependence and Spatial Variation of Spontaneously Generated Magnetic Fields in Laser-Produced Plasmas," Journal of Applied Physics 46, 1493 (1975).

P. Krehl, F. Schwirzke and A. W. Cooper, "Correlation of Stresswave Profiles and the Dynamics of the Plasma Produced by Laser Irradiation of Plane Solid Targets," Journal of Applied Physics, 46 4400 (1975).

Theses Directed:

Francis T. Williamson, "Laser Generated Magnetic Fields," Master's Thesis, June 1976. (Thesis Advisor: F. Schwirzke)

Daniel J. Callahan, "Laser Plasma Particle Velocities," Master's Thesis, June 1976. (Thesis Advisor: F. Schwirzke)

Sydney A. Shewchuk, "X-Ray Diagnostics of Laser-Produced Aluminum Plasmas," Master's Thesis, June 1976. (Thesis Advisor: A. W. Cooper)

John F. Jacobson, "Examination of Laser-Produced Pressure Pulses in a Gallium Arsenide Solar Cell," Master's Thesis, June 1976. (Thesis Advisor: A. W. Cooper)

Title: Finite Amplitude Acoustic Waves in Cavities

Investigator: A. B. Coppens, Associate Professor of Physics and Chemistry

Sponsor: None

Objective: To obtain a physical understanding of the behavior of high amplitude acoustical standing waves in cavities with rigid boundaries. The goal is to be able to predict the nonlinear acoustical effects which arise in real cavities where boundary irregularities and physical imperfections of the system cannot be ignored.

Summary: This work represents a continuing effort over several years to obtain solutions to an emphirical nonlinear wave equation describing the behavior of nonlinearly-distorted standing waves in real tubes and cavities. Present efforts are devoted to solving this wave equation for standing waves in rigid-walled cavities of rectangular geometry. The Theoretical predictions of the bahavior of the nonlinearly-generated harmonics of a driven standing wave in the cavity are in agreement with experiment for cavities with very good geometry. The frequency dependence of the amplitudes of the harmonics depends on the exact relationships between the observed resonance frequencies and absorption coefficients of the real cavity. This means that calculated resonance frequencies and absorption coefficients of the cavity are not sufficiently accurate to predict the observed behavior of the standing wave. We are now investigating solutions of the nonlinear wave equation for cavities containing simply perturbed boundaries. The results look promising, and demonstrate the possibility of coupling energy into normal modes (otherwise unexcited) by means of finite-amplitude perturbation corrections to the finite amplitude solution in the unperturbed cavity.

Publications: A. B. Coppens and J. V. Sanders, "Finite Amplitude Standing Waves Within Real Cavities". Journal of the Acoustical Society of America (1975).

Theses Directed: Milo J. Kilmer II, "Finite Amplitude Effects in Rectangular Cavities with Perturbed Boundaries", Master's Thesis, December 1975.

Winfield S. Slocum IV, "Finite Amplitude Standing Waves in Real Cavities Containing Degenerate Modes", Master's Thesis, December 1975.

John J. Donnelly, "Investigation of Subharmonic Generation by Finite Amplitude Waves in a Rigid-Walled Tube", Master's Thesis, June 1976.

Title: Optical Propagation in the Marine Boundary Layer (Optics)

Investigators: E. C. Crittenden, Jr., A. W. Cooper, S. H. Kalmbach, E. A. Milne, G. W. Rodeback, and R. L. Armstead, Professors of Physics and Chemistry

Sponsor: Naval Sea Systems Command

Objective: To develop methods for predicting the optical propagation properties in the marine boundary layer on the basis of the bulk properties of the atmosphere, and to determine the dependence of the optical properties on the micrometeorology in the marine boundary layer.

Summary: Knowledge of the optical properties of the atmosphere over land has been sketchy, and over the ocean has been almost nonexistent. Such knowledge is vital for the design, and prediction of performance in the marine environment, of a wide range of military applications of electro-optics - specifically for target detection, ranging, pointing, tracking, homing, imaging and communications. The major properties of interest are the "seeing" or resolution through the atmosphere, as it is degraded by turbulence and aerosols, the "scintillation" or intensity fluctuations and the angle-of-arrival fluctuations (image wander) of a transmitted beam, and the extinction, or loss of energy from a beam, by absorption and scattering of radiation by fog and aerosol particles. The "seeing" is characterized by the Modulation Transfer Function (MTF) and the closely related Mutual Coherence Function (MCF) which also determines the signal-to-noise ratio in a coherent detection receiver. Image wander and its frequency spectrum are also involved in determination of seeing. The scintillation is characterized by the Optical Turbulence Structure constant C_n. Measurement of scintillation over a horizontal path yields a value for C_n averaged over the path; point values of C_n^2 can be obtained by meteorological methods. During the past three years techniques have been developed for measuring these parameters under open-ocean conditions with both shore-to-shore and ship-to-shore paths, using the Naval Postgraduate School (NPS) research vessel, ACANIA, for ranges up to 20 km. Optical measurements of scintillation, image wander and

MTF are made simultaneously with meteorological measurements.

Measurements have been made under a variety of conditions with lasers at wavelengths of .488 μm (blue), .6328 μm (red), 1.06 μm (near IR) and 10.6 μm (far IR). Broad band detection with black body sources has been carried out in the middle IR band from 3-5 μm. On-line data reduction is in operation for the determination of C_n from scintillation. MTF is determined by Fourier analysis of the line spread image function obtained with a telescope. The data is recorded for later processing by computer. An on-line data reduction system is under construction to yield direct MTF results in the field. A portable compact system has been developed for measuring the MTF on-site in connection with other optical experiments elsewhere.

Extinction, the loss of light from a beam as as a result of aerosol scattering, has been measured over the same optical paths as for MTF and C_n, in order to incorporate the effects of scattering in the prediction of MTF. Measurements of fog/aerosol parameters are simultaneously made on shipboard during the optical measurements, in a companion research project headed by Professor Schacher. The micrometeorology is simultaneously measured in another companion research project headed by Professor Davidson in the Department of Meteorology. Comparison of the experimental results with theory indicates a substantial inadequacy of the capability of current theoretical models to predict MTF of an optical path on the basis of C_n values obtained either from scintillation over the same path or from thermal fluctuation measurements at points along the path. Experimental work is in progress to determine the cause of this inadequacy. MTF measured by a shearing interferometer in a joint experiment with MIT Lincoln Lab gave essential agreement with the NPS values, and corroborated the inability of theory to predict MTF from C_n on present models.

Publications:

E. C. Crittenden and K. L. Davidson, "Laser Transmission in the Marine Environment", Naval Research Review, February 1976.

Title: Development of an Improved Ray-Tracing Algorithm for Underwater Acoustic Ranges

Investigator: Harvey A. Dahl, Assistant Professor of Physics and Chemistry

Sponsor: Naval Tropedo Station

Objective: The purpose of this work was to produce and test an improved computer program by means of which the position of a sound source in an underwater range could be determined accurately using only the signal arrival times at the four hydrophones of a single array on the range. Current programs which do this were known to produce significant errors, particularly in the depth coordinate.

Summary: The calculation of position is broken into two steps. The first of these is the determination of the angle of elevation of the arriving ray and of the effective time of flight to the center of the given array of sensors. A new algorithm has been produced which caculates these quantities on the assumption that sound speed varies linearly with depth (isogradient case). The calculation involves hyperbolic functions of the travel times to the four hydrophones and is slightly more cumbersome than the old algorithm which was based on the assumption that sound speed in the water is a constant (isovelocity case).

The second part of the calculation is the actual tracing back along the ray from the array center, starting with the angle of elevation from step one, and proceeding until all the time is consumed and the predicted source position is reached. The new traceback program considers the water to be composed of horizontal, ten-foot thick isogradient layers. The traceback occurs along a ray composed of circular segments with different radii in the successive layers, with matching slopes at the layer boundaries.

The complete program has been tested on models of the range in which the water is broken into one, two, or three horizontal isogradient layers. Current NTS isovelocity programs used on these models produce depth errors of about 1 ft due to elevation angle error alone and another 1.7 ft due to traceback errors, for a total depth error of 2.7

ft, all at 3,000 ft horizontal range from the array. Use of the new NPS algorithm, on the other hand, results in depth errors of less than 0.05 ft total for the same horizontal range in these models. Horizontal position errors, though not very large in either development, are reduced by a factor of about 5 to a value of about 0.01 ft by use of the new program.

Motivation for this study and a slightly expanded description of the effort may be found in the Ray-Tracing Task Group portion of the following report.

Publications:

O. B. Wilson (Editor),"Annual Summary Report of the Range Study Program", NPS-71W176081, August 1976.

Title: Torpedo Tracking

Investigator: H. A. Dahl, Assistant Professor of Physics and Chemistry

Sponsor: Naval Torpedo Station

Objective: The application of Kalman Filtering to torpedo range tracking.

Summary: The application of Kalman filtering to the on-line real-time tracking problems at Keyport as well as for improving the post-run data analysis is underway. Two thesis students are involved in the project. A workshop in Kalman filtering has been presented to engineers at Keyport. A tape of a torpedo track has been obtained and is presently being used to check out our computer tracking algorithm for this application. When a sufficient confidence in the program is obtained we will put the program on the computers at Keyport and test it in a real-time environment. The two thesis students will complete their work this fall and a report is in progress.

Publications: None

Title: Computer Simulation of Sputtering III

Investigator: Don E. Harrison, Jr., Professor, Physics and Chemistry Department

Sponsor: Foundation Research Program (6.1)

Objective: To prepare for publication previous investigations of the formation of clusters of particles sputtered by atomic ions, and to pursue the investigation, by computer simulation, of the sputtering of a copper surface by diatomic molecular ions.

Summary: (1) The paper was prepared and has been published, see Publications below.
(2) The main thrust of the molecular sputtering effort has been suspended while further details of the atomic sputtering process are examined. A careful examination of the sputtering ratio, atoms sputtered per incident ion, as a function of the ion mass indicates that the momentum transfer mechanisms are quite different for small and large mass ratios. There are now clear indications that a light bullet sputters atoms near the impact point while heavy ions produces a liquid droplike effect. For heavy ions the near atoms do not sputter, but a ring of atoms approximately 5 Å from the impact point do. This effect must be studied in greater detail. An immediate consequence is that computation will be more time consuming for heavy ions because the target microcrystallite must be larger. The project will continue in FY77.

Publications: Don E. Harrison, Jr. and C. D. Delaplain, "Computer Simulation of the Sputtering of Clusters," Journal of Applied Physics, 47, 2252-59, (1976).

Title: Compilation of Vacuum Ultraviolet Spectra

Investigator: R. L. Kelly, Professor of Physics and Chemistry

Sponsor: National Aeronautics and Space Administration, Goddard Space Flight Center

Objective: To prepare a complete and accurate compilation of atomic spectrum lines with wavelengths less than 3000 Angstroms, based on publications in the open literature.

Summary: An important part of any field of science is the utilization of measurements which have already been made. Frequently, however, the available information is fragmentary, of questiononable value, or is not easily located in the various journals. The Spectroscopic Data Center is a repository of all available information on optical transitions in atoms and ions of the elements through Krypton. These data are continually up-dated and evaluated, so that fragmentary information is put into the larger picture, and doubtful information is eliminated.

Compilations are published from time to time, the latest being NRL 7599, "Atomic and Ionic Emission Lines Below 2000 Angstroms," June 1973. This report contains the wavelength, intensity, and classification of 34,700 spectrum lines with wavelengths in the vacuum region, from all observed stages of ionization. Entries are arranged by element and spectrum, with a separate finding list. Following the publication of this report, up-dating the data files has continued. More than 200 new publications with relevant information have appeared. Evaluation of the new and old data is a continuing task, certainly one of the most important. In addition to the compilations published, the files are available to users as magnetic tapes and punched cards. These forms of data file have been used by astrophysicists and plasma physicists.

A specific task nearing completion of data on the 2000-3000 Angstrom region. Approximately 30,000 lines have been observed in this region of the spectrum. Lack of information on several inportant ions indicates the need for more laboratory observations.

Publications: None

Title: Thermodynamics Calculations for Internal Blast

Investigator: G. F. Kinney, Professor Emeritus, Department of Physics and Chemistry

Sponsor: Naval Weapons Center

Objective: To make theoretical thermodynamic calculations for the pressure and temperature rises developed in the internal blast produced by an explosion in a confined space. This is a continuing program.

Summary: An explosion in a confined space such as a ship or aircraft compartment produces an internal blast by pressure rise as energy release raises the temperature of confined air and as gases are formed in the explosion. Important here is chemical dissociation in the reaction zone which acts as an energy sink and so limits the pressure rise that can be produced.

A computer program for characterizing these effects has been developed. This involves the solution of twelve simultaneous non-linear equations. Its results have been found to agree, within experimental uncertainty, with observed values for TNT as reported in the literature. These calculations show that an explosion with an ordinary fuel such as fuel oil has a maximum peak overpressure at a fuel-air ratio that is intermediate between the CO_2-H_2O and CO-H_2O stoichiometric points. For explosive fuels such as TNT or PETN the internal blast pressure increases monatonically with the amount of fuel.

Publications: None

Title: Environmentally Adjusted Signal Enhancement

Investigator: H. Medwin, Professor of Physics and Chemistry

Sponsor: Naval Seas Systems Command

Objective: To study means for adjusting an ocean acoustics signal in response to the fluctuating medium in order to enhance its strength and to improve its stability.

Summary: Recent research has shown that significant improvement in passive signal strength and reliability can be achieved by appropriately applying phase shifts. To optimize this technique the dependence of the improvement on the size and location of the hydrophone in the incoherent field, and the acoustical roughness of the surface will be investigated for a broad range of frequencies.

Publications: None

Title: Upper Ocean Parameters Affecting Sound Propagation

Investigator: H. Medwin, Professor of Physics and Chemistry

Sponsor: Office of Naval Research

Objective: To characterize the statistical relations between ocean wave spectra, underwater turbulence temperature microstructure bubble populations, and propagation of acoustic energy near the sea surface.

Summary: Computerized equipment has now been used to obtain data on sound speed dispersion, attenuation and inferred microbubbles in the upper ocean. The experiment is continuing in search of the interrelations between physical and biological ocean parameters, bubble presence, and sound propagation under various ocean conditions.

Publications: H. Medwin, "Acoustical Probing for Microbubbles at Sea", Proceedings of a Conference on Oceanic Acoustic Modelling. SACLANT ASW Research Center La Spezia, Italy, 15 October 1975.

Title: Preparation of Laser Effects Handbook

Investigator: John R. Neighbours, Professor of Physics and Chemistry

Sponsor: Naval Surface Weapons Center

Objective: This continuing project is to present the effects of high energy laser irradiation of materials in a single source. Much of the data results are from the NRL Materials Effects portion of the Optical Radiation Program, but all three services and the civilian sector are surveyed.

Summary: The principal investigator receives directly a large number of pertinent classified reports which serve as a beginning data base. Several faculty members have participated with the principal investigator serving as Editor. Procedure has been for each participating faculty member to have responsibility for a particular topic. After becoming familiar with recent work in the field, the participating faculty member has made field trips to visit important research workers. This method allows personal interaction with a research worker as well as transmittal of information.

Publications: John R. Neighbours and A. J. Perkins, "NPS Laser Effects Handbook," Technical Report NPS-61-61Nb75091, August 1975.

Title: Homogeneous Catalysis by Palladium Complexes

Investigator: R. A. Reinhardt, Professor, Physics and Chemistry Department

Sponsor: Foundation Research Program (6.1)

Objective: To study the kinetics of olefin oxidation by a series of palladium complexes. This is part of the continuing research into ligand substitution processes.

Summary: As a continuation of experiments begun previously, the rate of oxidation of trans-2-butene to 2-butanone by $PdBr_4^{2-}$ in acidic aqueous media is being studied. The use of gas chromatography to follow the reaction permits monitoring the actual concentrations of both reactant and product as functions of time. From data thus far obtained over a limited range of concentrations of acid and bromide, the reaction mechanism appears to be the same as that found in chloride solutions, with nearly the same value found for the formation constant of the precursor complex, but a rate of reaction of this precursor to product an order of magnitude less with bromide than with chloride.

Future plans: once the $PdBr_4^{2-}$ study is properly completed, we shall examine the reaction with other complexes, using the stopped-flow apparatus when appropriate for the more rapid processes, as is expected with the tetraaquo complex.

Conference Presentations: R. A. Reinhardt (presenter) and K. J. Graham, "Kinetics of Oxidation of Olefins by Palladium (II) Complexes." Paper presented to the 31st Meeting of the Northwest Region of the American Chemical Society, Reno, Nevada, 15 June 1976.

Publications: None

Title: Characteristics of Resistance Wires Used for Atmospheric Turbulence Measurements in the Marine Environment

Investigators: Gordon Schacher, Associate Professor, and C. W. Fairall, Assistant Professor, Physics and Chemistry Department

Sponsor: Foundation Research Program and Naval Air Systems Command

Objective: The purpose of this project is to determine the effect of marine aerosols on resistance wires which are used to measure fluctuations in wind speed and temperature. This is a continuing project.

Summary: Resistance wires are used as sensors to measure fluctuations in air temperature and wind speed. Such measurements are being made at NPS in the marine environment where the wires are impacted by marine aerosols, primarily saline droplets, resulting in sea salt encrustation. It is possible for thick layers of salt to change the calibration of the wires and measurements of the responses of wires that have been encrusted in the laboratory. The laboratory coatings are much thicker than that normally produced by sea spray in the field, and enabled a change in wire sensitivity to be measured. Both the dc and ac response of hot wires used for wind speed measurements have been investigated and it is found that naturally occurring levels of encrustation are rarely sufficient to significantly affect wire calibration, and that it is possible to easily test to determine if the wires are severely coated. Measurements on temperature wires are in progress and the effects of fog droplet impaction will be investigated in the future.

Publications: Gordon Schacher and C. W. Fairall, "Use of Resistance Wires for Atmospheric Turbulence Measurements in the Marine Environment," Review of Scientific Instruments, 47, No. 6, 703, 1976.

C. W. Fairall and Gordon Schacher, "Frequency Response of Hot Wires Used for Atmospheric Turbulence Measurements in the Marine Environment," Review of Scientific Instruments, 47, No.12, 0065, 1976.

Title: Plasma - Surface - Interaction

Investigator: F. Schwirzke, Associate Professor of Physics and Chemistry

Sponsor: Energy Research and Development Administration, Division of Magnetic Fusion Energy

Objective: To perform an independent review of impurity studies and diagnostics in tokamak systems, make recommendations and submit a comprehensive plan for action.

Summary: Since adequate magnetic confinement and heating of a deuterium-tritium plasma seems possible, impurity evolution due to plasma-wall interaction and impurity control are recognized now as being the critical remaining obstacles on the way to magnetic fusion energy. Impurities adversely influence almost every aspect of plasma behavior in the toroidal magnetic confinement system tokamak. Most tokamaks lose a large fraction of the power input by impurity radiation. High-Z impurities are particularly harmful since they are only partially stripped of electrons in the hot plasma and therefore radiate strongly. The tolerable impurity level for ignition of fusion reactions is so low that active impurity control is imperative for future fusion reactors.

Conference Presentation: (1) "Laser-Induced Desorption of Gas from Metallic Surfaces"presented by F. Schwirzke, IEEE Conference Record, 75CH0987-8-NPS, Second International Conference on Plasma Science, Ann Arbor, Michigan, p. 121 (1975).

Publications: F. Schwirzke, H. Brinkschulte and M. Hashmi, "Laser-Induced Desorption of Gas from Metallic Surfaces," Journal of Applied Physics, (1975).

Title: The Influence of Coatings and Self-Generated Magnetic Fields on X-ray and Particle Emission from a Laser Produced Plasma.

Investigator: F. Schwirzke, Associate Professor of Physics and Chemistry

Sponsor: Air Force Office of Scientific Research

Objective: To investigate the processes which influence the emission of x-rays and fast particles from a laser produced plasma.

Summary: Measurements have been made of the expansion of a laser produced plasma, and the data have been correlated to the target impulse measured with a quartz pressure gauge. Also, a number of experiments were conducted to assess the effects of thin coatings with varying optical properties on the stress wave generation at the surface of targets. Stress enhancement of up to a factor of 10 has been observed with transparent coatings. The results suggest that the enhanced stress is caused by temporarily trapping of the plasma at the target coating interface.

The proper use of magnetic fields represents another promising method to enhance the x-ray emission from a laser produced plasma. Magnetic fields are generated in a laser produced plasma by nonaligned density and temperature gradients. These magnetic fields may be quite large near the focal spot region and thus can influence the dynamics and heat conduction of the electrons. After successive burst of laser energy on the same spot a crater is formed in a metal target. In this case the lateral excape of plasma to the walls of the crater will be reduced by the existence of strong self-generated magnetic fields which can not diffuse into the conducting walls of the crater during the short time of the laser pulse. Due to limited expansion and heat conduction loss in radial direction the electrons can be heated to higher temperatures, and consequently the x-ray emission from the plasma in the crater can escalate to higher values.

Presentation: F. Schwirzke, A. W. M. Cooper, and F. T. Williamson, Jr., "Spontaneous Magnetic Fields in Laser-Impact Craters," Bulletin of the American Physical Society, 21, 1029 (1976).

Title: An Analysis of the Performance Limits of Coherent Anti-Stokes Raman Spectroscopy (CARS) as an Analytical Technique

Investigator: W. M. Tolles, Professor of Physics and Chemistry

Sponsor: Office of Naval Research

Objective: CARS is currently undergoing development as a means of gathering molecular spectroscopic information. This study was to determine quantitative estimates of the signal-to-noise ratio expected for specified experimental conditions.

Summary: The signal-to-noise relationships are obtained for Coherent Anti-Stokes Raman Spectroscopy (CARS) in addition to two commonly employed spectroscopic tools: absorption and Raman scattering. Similar assumptions are included for laser performance and other parameters affecting each spectroscopic technique. CARS offers the greatest signal-to-noise advantage when utilized to obtain high resolution spectra of gases at low pressure for species that do not have a dipole moment. For mixtures of gases at one atmosphere total pressure, ordinary Raman scattering appears to offer greater signal-to-noise ratios than CARS except for the notable exception of hydrogen gas, which has substantially narrower lines. Other experimental arrangements are simulated.

Publications: None

Thesis Directed: R. Turner, "An Analysis of Coherent Anti-Stokes Raman Spectroscopy as an Analytical Tool," Master's Thesis, June 1976.

Title: Range Studies Program

Investigator: O. B. Wilson, Jr., Professor of Physics and Chemistry

Sponsor: Naval Torpedo Station

Objective: To provide support for the Long Range Development Program of the Naval Torpedo Station, Keyport, Washington.

Summary: This is a continuation of a program initiated in 1973 for participation by NPS and NTS in projects of mutual interest and benefit. NTS personnel present, on an irregular basis, seminars at NPS on subjects of mutual interest. NPS faculty members and their students participate in studies of long range problems in the development of the NTS facilities and capabilities.

Nineteen members of the NPS faculty participated in the program during FY76. The total effort was divided into eight parts each which was attacked by a task group consisting of from one to eight faculty plus students. The work of these groups is reported individually elsewhere in this document under the name of the task leader as Investigator. The name of each participant in these task groups and reports and theses resulting from their work is also listed. The task groups for FY76 were as follows:

Task Group	Task Leader
1. Range Requirements	Assoc. Prof. D. A. Stentz
2. Signal Coding	Prof. D. B. Hoisington
3. Transducers	Prof. O. B. Wilson, Jr.
4. Ray Tracing	Ass't. Prof. H. A. Dahl
5. Range Concepts	Assoc. Prof. A. R. Washburn
6. Non-Acoustic Sensors	Assoc. Prof. G. L. Sackman
7. Data Transmission, Processing and Display	Ass't. Prof. V. M. Powers
8. Electromagnetic Propagation	Assoc. Prof. J. B. Knorr

Publications: O. B. Wilson, Jr., "Annual Summary Report, Range Studies Program", Technical Report NPS-71WL76081, August 1976.

DEPARTMENT OF ELECTRICAL ENGINEERING

The Electrical Engineering research program encompasses a variety of areas, including: (1) Acoustics and Electro-Optics; (2) Bioengineering; (3) Electromagnetics; (4) Electronic Warfare Systems; (5) Information Processing Systems--Communications, Computer Applications, Estimation and Control, and Signal Processing; (6) Naval Tropedo Station Range Studies; and (7) Solid State Devices. The projects in each of these areas generally involve one or more faculty members working with several thesis students. A summary of the projects follows.

ACOUSTICS AND ELECTRO-OPTICS

Computer-aided acoustic imaging has been investigated by Professor John Powers with the objectives of implementing scalar diffraction integrals on a computer and magnetically recording the ultrasonic planar diffraction pattern. Professor Donald Stentz has studied seawater properties that cause scattering and absorption of light beams in order to determine factors which affect the operation of the Optical Ranging Identification and Communication (ORIC) System.

BIOENGINEERING

The neurophysiological research program directed by Professor George Marmont involves an investigation of human electroencephalogram characteristics of a subject performing a task in order to provide real time feedback signals to improve task performance.

ELECTROMAGNETICS

Techniques for measuring surface currents on ship-shaped objects were developed by Professor Richard Adler in his shipboard electromagnetic compatibility study. Professor Robert Burton has measured electromagnetic pulse (EMP) effects on aircraft communications systems. These measurements, when used with analytical results, provide a means of evaluating EMP simulation programs. Professor George Sackman has initiated a study of magnetic background noise with the objective of improving Navy systems for magnetic detection and degaussing of submarines.

ELECTRONIC WARFARE SYSTEMS

Techniques for phase-front distortion jamming of monopulse tracking radar systems have been investigated by Professor David Hoisington. The purpose of the project is to develop a feasible hardware implementation of the jammer.

COMMUNICATIONS

Professor Glen Myers has begun an investigation of interval modulation--a new technique for signal transmission--with the objective of determining the characteristics of this method. Professor Myers also studied the use of frequency division in demodulating FM carrier signals. Shipboard radio frequency interference (RFI) in the UHF SATCOM System has been the subject of a research program directed by Professor John Ohlson. The objectives of the study have been to characterize the RFI shipboard environment and to develop a simulator to be used in improving future SATCOM receivers.

COMPUTER APPLICATIONS

An adaptation of the USAF noise analysis program NOISEMAP was developed by Professor John Duffin who also devised computer programs to perform air emission analysis and to provide aircraft noise contour data plotting.

ESTIMATION AND CONTROL SYSTEMS

Professor Harold Titus has investigated tracking algorithms for military systems, including techniques for acoustic tracking, optimal scanning for two-dimensional tracking, Kalman filtering algorithms for the Position Locating Reporting System (PLRS), and an improved Kalman filtering algorithm for optimally resetting strap-down laser gyros. Professors George Thaler and Alex Gerba have continued validating and updating a digital simulation program for captured air bubble type surface effect ships. This simulation program will be utilized in predicting dynamic characteristics and control strategies for this new class of ship.

SIGNAL PROCESSING

Various aspects of Signals Intelligence (SIGINT) systems and Tactical Airborne Signal Exploitation Systems (TASES) were investigated by Professor Stephen Jauregui. Professor George Marmont continued development of his tegulometric analysis technique which can be applied to detection of frequency signatures in a complex multi-source signal. Professor Tien Tao investigated the application of recursive comb filters, synthesized using Charge Transfer Devices (CTD's) to Moving Target Indicator (MTI) radar signal processing. Procedures for designing recursive filters using CTD's have also been developed.

RANGE STUDIES

Several faculty members in the Electrical Engineering Department have participated in the Range Studies Program. Professors Hoisington and Myers participated in the development of a phase-coded transmission system used for position location of range vehicles. Professor Jeffrey Knorr initiated an electromagnetic propagation study for determining tropospheric path loss for transmission of voice and data communications in support of range activities. An electrical circuit was designed by Professor Glen

Myers to simulate the attenuation and phase shift characteristics of seawater over a distance of 1000 yards in the frequency range 50 kHz to 100 kHz. Professor Sackman led a task group investigating magnetic sensors and magnetic "silencing." Professor Harold Titus investigated the application of Kalman filtering to torpedo range tracking.

SOLID STATE DEVICES

Fabrication of a high dielectric constant insulator by a low temperature process compatible with non-silicon semiconductors has been carried out in a project directed by Professor Tien Tao. This fabrication process has applications in the area of infrared charge coupled imaging systems.

Title: Shipboard Electromagnetic Compatibility study

Investigator: Richard W. Adler, Electrical Engineering

Sponsor: Naval Electronics Laboratory Center

Objective: To develop techniques for measuring surface currents on ship-shaped objects such as rectangular prisms with monopole antennas.

Summary: The Navy is currently developing an Integrated Technique for Electromagnetic Analysis which will provide a computer modeling capability for shipboard electromagnetic compatibility studies. To validate the computer codes, a set of measurements must be made. This project provides these unique measurements as a deliverable item.

Publications: C. T. Ristorcelli with R. W. Adler, "Electrical Characteristics of Monopole Antennas above a Rectangular Prism", Technical Report NPS52A675121, December 1975.

Title: Experimental and Theoretical Investigation of Electromagnetic Pulse (EMP) Effects on Aircraft Communication Systems

Investigator: R. W. Burton, LT COL, USAF , Associate Professor of Electrical Engineering

Sponsor: Air Force Weapons Laboratory and Rome Air Development Center

Objective: To determine by measurement the charge and current densities on analytically tractable models of aircraft which are exposed to electromagnetic pulse (EMP) radiation. From a study of measured and analytic results, insight may be gained to evaluate actual aircraft EMP simulator programs.

Summary: The work during this reporting period extended the measurement techniques and methods of analysis developed in the study of electrically thin (ka= .2) receiving crossed monopoles reported earlier to electrically thick (ka = 1) crossed monopoles which are respectively the low frequency and high frequency models used to study aircraft structures exposed to the broadband electromagnetic pulse. Measurement of charge and current distributions on scattering flat plates have been completed which give insight into analysis of aircraft wing structures. A complete characterization of charge and current distributions in the area of electrically thick wing junction regions has been accomplished.

Publications:

Burton, R. W., "On Measuring Elliptically Polarized Surface Currents," Published in Proceedings of National Conference on Electromagnetic Scattering, June 1976

McDowell, E. J.; Burton, R. W., "Charge and Current Distributions on, and Input Impedance of Moderately Fat Transmitting Crossed-Monopole Antennas," Technical Report NPS-52Zn76031, March 1976.

Wiedemann, H. J.; Burton, R. W., "Measured Surface Charge and Current Distributions on Scattering Rectangular Plates," Technical Report NPS-52Zn76051, May 1976.

King, R. W. P.; Burton, R. W.; Shen, L. C., "Electric and Magnetic Fields Induced on the Surfaces of Electrically Thin and Thick Cylinders and Crossed Cylinders by an Incident Plane Wave," published in Proceedings of National Conference on Electromagnetic Scattering, (invited paper) June 1976.

Title: Adaptation of USAF Computerized Noise Analysis Program "NOISEMAP 3.2"to IBM System 360-Mod 67 Located at NPS, Monterey, California

Investigator: J. H. Duffin, Professor of Electrical Engineering

Sponsor: Naval Air Rework Facility

Objective: The U. S. Air Force noise analysis program "NOISEMAP 3.2" be adapted to the NPS system 360 computer. This program had been changed from CDC type Fortran to IBM type by Bolt, Beranek and Newman. The changed program contained many "bugs" which were to be removed to make the program operational. The prcgram was then to be used for production type runs using noise survey data from various Naval Air operations centers.

Summary: Program NOISEMAP 3.2 was set up on the NPS system 360. A number of program bugs were found and eliminated but by no means all of them. Due to size and complexity of the program, it was necessary to have NARF-NORIS personnel come to Monterey to make runs. An effort to eliminate these visits involved an attempt to exchange information with NARF-NORIS via data communication lines with Monterey's System 360 "talking" to North Island's Wang 2200C. It was found that the data transmission rate was too slow to be useful - mainly due to hardware limitations on the Monterey end.

In view of these difficulties, NARF-NORIS decided to look elsewhere for high-speed data transfer/time-share-console type use. They found what they needed with Tymshare Corp. of Cupertino, California. As a result all effort on this project has been discontinued as of March 1976. NOISEMAP 3.2 is still in the NPS computer system and may be used again but it is not likely.

Publications: None

Title: Creation of Various Wang 2200C Minicomputer Programs

Investigator: J. H. Duffin, Professor of Electrical Engineering

Sponsor: Naval Air Rework Facility

Objective: There were several relatively small problems in the areas of noise analysis, air emissions analysis etc., that NARF-NORIS needed to have computerized. In addition, their Wang 2200-C had just had a large flat-bed plotter added into its hardware configuration and the Wang supplied software plotting package needed to be customized for NARF-NORIS use. Therefore, it was the objective of this work to create various software packages to meet the diverse needs of the Air Emissions Support Office (AESO) located at NARF-NORIS.

Summary: This work was performed during the investigators intersessional period of approximately 15 October 1975 to 15 December 1975. No further work was or will be done after the latter date.

A series of 12 software packages were created, tested and put into use to cover the various needs of the NARF-NORIS AESO group. The major part of the time was spent in adapting the Wang plotting package to the general plotting needs. Specific applications of the plotting software were in air craft noise data contour plotting. Others were in general data plotting. Editing and report generation software packages were created. All software packages operated successfully and were acceptable to all parties concerned.

Publications: None

Title: Range Studies Program; Phase-Coded Clock

Investigators: D. B. Hoisington, Professor of Electrical Engineering and G. A. Myers, Associate Professor of Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: To provide consulting services in the development of a phase-coded acoustic transmission system to be used for locating vehicles on the Naval Torpedo Station Tracking ranges.

Summary: The Naval Torpedo Station is developing a phase coded system to replace the present uncoded 75 kHz synchronous pulse transmitters for the 3-D tracking ranges operated by the Station. Objectives are improved tracking accuracy through improved use of available bandwidth, and the ability to transmit telemetry signals on the pulse. During Fy 76 a number of system tests were conducted on the NTS ranges, and improvements made in the system. The final result is a system that fully meets the requirements laid down for it. Improved tracking accuracy results in smoother tracks of vehicles with fewer data point drop outs. The telemetry system is highly reliable. NPS personnel participated in system tests during the year, and provided consulting service for NTS personnel. To facilitate testing of systems involving transmission of signals through water in the vicinity of 75 kHz, a transmission simulator was designed. This device approximates the phase shift and attenuation vs frequency transmission characteristics of water in the range from 50 to 100 kHz over a path length of 1000 yards. Sections can be cascaded to simulate greater path lengths.

Publications: O. B. Wilson (Editor), "Annual Summary Report of the Range Studies Program," Technical Report NPS-71wl 76081, August 1976.

Title: Jamming of Monopulse Tracking Radars

Investigator: David B. Hoisington, Professor, Electrical Engineering

Sponsor: None

Objective: To investigate phase-front distortion jamming of monopulse tracking radars.

Summary: At the present time no practical jammers exist for providing angular deception of monopulse tracking radars. Phase-front distortion generated by an interferometer pair has been proposed. Although some success has been achieved in tests, it has not been possible to convert this into useful equipment. The purpose of this research is to find techniques that can be used to construct a viable phase-front distortion deceptive monopulse jammer. Computer simulation was first used to investigate the effects of amplitude and phase deviations from optimum values, and the effects of amplitude and phase modulation. A range was constructed using the NPS Nike-Ajax monopulse radar for validation of the simulation results. Significant angular errors were induced in the radar tracking system. This work is continuing in FY 7T-FY-77 with NAVSEA sponsorship.

Thesis Directed: M. J. Ducan, "Design of a Repeater-Jammer Experiment for a Monopulse Radar," Master's Thesis, September 1975.

Title: Range Studies Program: Electromagnetic Propagation Task

Investigator: J. B. Knorr, Associate Professor of Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: The Electromagnetic Propagation study is one of several tasks included in the Range Studies Program sponsored by the Naval Torpedo Station at Keyport, Washington. The objective of this study is to determine path loss for tropospheric circuits, both existing and proposed, for the transmission of voice and data communications in support of Keyport range activities.

Summary: Work was begun on this task in January 1976 and during the first phase of the study the Naval Postgraduate School computer Program TROPOPLOT was used to determine long term median values of basic path loss for the troposhere curcuits of interest. TROPOPLOT is based on the ESSA technical report ERL 79-1TS67. This work has been reported as described below. During AY 76-77, work will be continued with the objective being the definition of the short term and long term variations in loss for the tropospheric paths. It is anticipated that both theoretical and experimental studies will be carried out.

Thesis Directed: R. M. Cassidy, "Computer Prediction of Tropospheric Radio Transmitted Loss for Selected Paths in the Pacific Northwest," Master's Thesis, June 1976

Title: Neurophysiological Research Program

Investigator: G. Marmont, Professor of Electrical Engineering

Sponsor: Naval Electrical Systems Command

Objective: The objectives of the Neurophysiological Research have been:

(1) To detect and analyze the human electroencephalogram (EEG) taken while a subject is performing a mental task.

(2) To develop from the analysis a feedback signal, in real time, which would, when presented to the subject, reinforce him in his task effort.

Summary: The research has been successful in meeting the above objectives. A distinctive type of EEG signature, the "tegule" was discovered. A tegule is a waxing and them waring sinusoid of a distintive frequency, seen as one of the components of the complex EEG record. When a subject is engaged in a demanding task, a sequence of tegnlic in a certain preferred frequency range are detected. The tegule frequencies tend to center in the 70 to 100 H_Z range.

A biofeedback signal has been derived (in real time, with a 1/4 second up date) from the cross-correlation of the digitally filtered response from two closely spaced EEG electrodes. Subjects respond to the signal, which is presented as a varying degree of ambient illuminations, as an indication of of their performance.

Because of the multi-demensional nature of the EEG signal, much further investigation of the effects observed is called for. Various aspects of this research area are the subjects of current thesis effort by several students.

A spin off from this research has been the tegulometric method of frequency signature analysis.

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A SUMMARY OF THE NAVAL POSTGRADUATE SCHOOL RESEARCH PROGRAM.(U)
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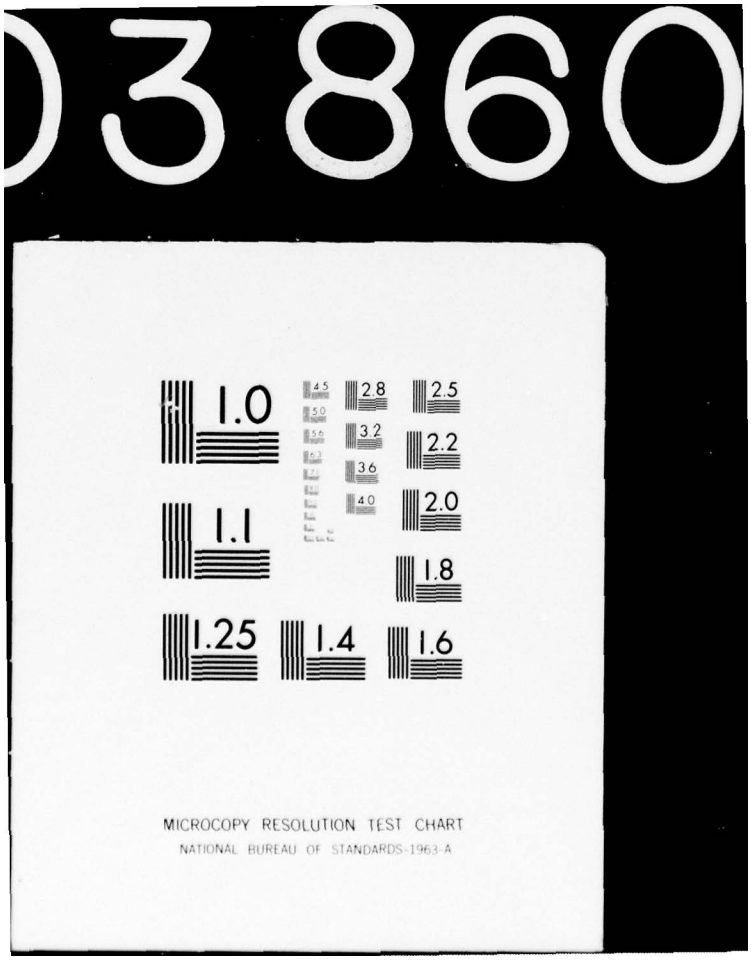
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Theses Directed:

Nizamettin Cetinyilmaz, "Application of the Computer for Real Time Encoding and Decoding of Cyclic Block Codes," Master's Thesis, December 1975.

Robert E. Dzialo,"An Analysis of Motor Function and Control in the Human Nervous System," Master's Thesis, December 1975.

Douglas D. Frisbie, "Preferred Frequencies in the Human Electroencephalogram," Master's Thesis, December 1975.

Dennis C. Marvel, "A Versatile System for Interfacing Subject to Task in EEG Analysis with Biofeedback," Master's Thesis, December 1975.

Peter S. Pierpont, "Improvement and Testing of 40 KHZ FM Modulated Underwater Communications System for Free Swimming Divers," Master's Thesis, December 1975.

Dennis C. McCormich, "Preferred Frequencies of the Human Electroencephalogram in Response to Auditory Stimuli," Master's Thesis, June 1976.

Hugh P. Parsons, "Frequency Analysis of Human Electroencephalogram in the Process of Performing Specific Tasks," Master's Thesis, June 1976.

Title: Tegulometric Analysis

Investigator: G. Marmont, Professor of Electrical Engineering

Sponsor: Naval Electronics Laboratory Center

Objectives: The tegulometric method of analysis has proved to more sensitive, by an order of magnitude, in detecting frequency signatures present in a complex, multi-source signal as compared to more conventional methods such as discrete fourier transform analysis. The priciple objectives are:

(1) To apply the method effectively in analysis of such signals as ASW sonograms and electroencephalograms.

(2) To further develop techniques for detection of very weak signals buried in noise.

(3) To apply the method to other types of signals, using frequency translation techniques where required.

It is expected that NELC will continue support of this research effort, with the goal of leading to operational devices.

Summary: Tegulometric analysis implies the dissection of a complex signal which is a summation of signatures from many sources and contamination with "noise". When one examines a time domain representation of the signal having a narrow frequency range, a tegular structure becomes apparent. (A "tegule" is defined as a waxing and then waring sinusoid). Because the tegules from the same or from several sources overlap in an irregular mannar, there are many times when a momentarily stronger tegule "captures" its weaker neighbors. Identification of the frequency of the momentarily stronger tegule can be measured via a zero-crossing algorithm. Each new frame of data is scanned with a narrow band frequency operating the relative occurrence of component frequencies determined, and the counts deposited in a histogram block having frequency as the abscissa.

New developments of the method include testing of the method on ASW phonogram recordings and a comparison of the results versus those

using current operational FFT types of analysis. Tegulometric analysis shows about an order of magnitude improvement in sensitivity.

Further development, still under way, is the extension of the method to the detection of very weak signals buried in noise. Additional computational techniques, only feasible with fast digital processing, have helped reveal S/N ratios of -24db, the noise being measured on a 1 HZ bandwidth basis.

Publications: None

Title: Use of Frequency Division in Demodulating FM Carrier Signals

Investigator: G. A. Myers, Associate Professor of Electrical Engineering

Sponsor: Naval Electronics System Command

Objective: To measure the performance of frequency demodulators that use frequency division before demodulation.

Summary: Binary digital data was used to frequency modulate (FM) a carrier. Noise was added to this FM signal. The sum of signal and noise voltages was applied to a divide-by-N circuit which reduced the carrier frequency and signal bandwidth by factors of $\frac{1}{N}$. A pulse counting demodulator (PCD) was used to recover the binary data. Errors were counted to form a plot of probability of error vs signal-to-nose ratio. Results for values of N = 1, 2, 6, 8 and 12 are tabulated. From these experimental results, it is concluded there is no significant improvement in system performance with frequency division.

Publications: Duong Tuan Viet, "Measured Effects of Frequency Division on the Performance of Pulse Counting Frequency Demodulators," Master's Thesis, July 1976

Title: Range Studies Program; Range Display and Water Simulator Studies

Investigator: G. A. Myers, Associate Professor of Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: To become familiar with a 3-D instrumented range and to relate such a system to the future requirements of the ranges of the Naval Torpedo Station.

To design an electrical circuit which would simulate the effects of the propagating medium on a sonar signal.

Summary: A visit was made to Miramar Naval Air Station, San Diego to observe the display subsystem of the Air Combat Maneuvering Range (ACMR). Both in-flight and taped exercises were viewed. Information on system cost and capability was obtained and documented. It appears a system like the ACMR could be effectively used for the following Naval Torpedo Station Functions: real time control/safety/recovery and measurement of parameters required in proofing torpedoes and in research and development; playback and simulation in WSAT training and in other fleet exercises.

A circuit is synthesized which approximates the attenuation and phase shift vs frequency characteristics of sea water in the range 50 kHz to 100 kHz over a distance of 1000 yards. Component values are specified. Simulation can be achieved for ranges of M kiloyards be cascading M such networks (M is a positive integer). The chosen design provides an excellent simulation of the absorption of the assumed propagating medium in the frequency range 50 kHz to 100 kHz.

Publications: None

Title: An Investigation of Interval Modulation

Investigator: G. A. Myers, Associate Professor of Electrical Engineering

Sponsor: Naval Electronics Systems Command

Objective: To determine the effect of varying the time between bursts of a sinsusoidal carrier in accordance with a message to be transmitted, and to study means of recovering the message from such an interval modulated (IM) carrier.

Summary: Effort to date indicates that a phase - locked loop can be used to recover the message from a particular IM carrier. Present work is concerned with developing a versatile modulating circuit. Spectral analysis of the IM carrier is being initiated. Other work on this continuing area of research will include the measurement of effects of noise and the transmission of human speech.

Publications: None

Title: Shipboard RFI in UHF SATCOM

Investigator: J. E. Ohlson, Associate Professor Electrical Engineering

Sponsor: Naval Electronic Systems Command

Objective: This study is to characterize the radio-frequency-interference (RFI) environment on ships of the Fleet. Susceptibility to interference of the SATCOM receivers is to be evaluated. A simulator is to be built to test improvements in receivers. Anti-RFI techniques are to be developed and tested.

Summary: A test instrumentation package was developed and was used to measure RFI on board several ships during at-sea operations. The bit-error-rates of the AN/WSC-3 and AN/SSR-1 SATCOM sets have been measured. Desensitization characteristics of the two radios have also been determined. A shipboard RFI simulator has been built and is now an operational laboratory tool. The shipboard RFI environment has been characterized. Anti-RFI techniques are now being evaluated.

Publications:

R. W. Adler, J. E. Ohlson, B. K. Hollar, "Evaluation of the AS-3018/WSC-1(V) Shipboard Satcom Antenna," Technical Report NPS-52AB76031, March 1976.

R. F. Carlson and J. E. Ohlson, "Receiver Desensitization of the AN/WSC-3 Satellite Communications Set, "Technical Report NPS-620L76091, September 1976.

R. F. Carlson and J. E. Ohlson, "Receiver Densensitization of the AN/SSR-1 Satellite Communications Receiver," Technical Report NPS-620L76101, October 1976.

R. F. Carlson and J. E. Ohlson, "Bit-Error Rate Measurements on the AN/WSC-3 and AN/SSR-1 Satellite Communications Sets," Technical Report NPS-620L76102, October 1976.

J. E. Ohlson and T. C. Landry, "Shipboard Radio Frequency Interference in UHF Satellite Communications," Technical Report NPS-620L76103, October 1976.

T. D. B. Menlo and J. E. Ohlson, "ITU Registrations and Navy UHF SATCOM," Technical Report NPS 620L76104, October 1976.

G. B. Parker and J. E. Ohlson, "Deck Boxes for UHF SATCOM Radio Frequency Interference Study," Technical Report NPS-620L76105, October 1976.

F. E. Mace, Jr., and J. E. Ohlson, "A High Level Noise Blanker and RF Amplifier System for the UHF Band," Technical Report NPS-620L76106, October 1976.

D. C. Arneson and J. E. Ohlson, "A Level Density Analyzer for Shipboard RFI Measurements," Technical Report NPS-620L76107, October 1976.

A. R. Shuff and J. E. Ohlson, "Instrumentation Package for Measurement of Shipboard RFI," Technical Report NPS-620L76108, October 1976.

E. S. Brick and J. E. Ohlson, "A Simulator for Shipboard Radio Frequency Interference in Satellite Communications," Technical Report NPS-620L76109, October 1976.

Title: Computer-Aided Acoustic Imaging

Investigator: John P. Powers, Associate Professor of Electrical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: This study investigates the feasibility of using a computer to obtain images of objects from the amplitude and phase of the diffraction pattern caused by ultrasound reflected from or transmitted by an object. The specific objective of this period of research was to investigate the implementation of the scalar diffraction integrals on the computer and to design an experimental arrangement to magnetically record the ultrasonic diffraction pattern over a plane. This is a continuing project.

Summary: The study of the implementation of the diffraction integrals compared the Fresnel integral representation and a spatial frequency domain approach. Both techniques use two dimensional Fast Fourier Transform (FFT) algorithims but differ in their geometry and in other respects. Based on the considerations that a computer aided imaging technique would require several evaluations of the integrals at arbitrary distances and that the spatial frequency approach is compatible with all frequency domain operations (e.g., Weiner filtering), it was concluded that the implementation in the spatial frequency domain was advantageous for use in imaging systems that might include an image processing capability. During the course of study computer programs for both diffraction integrals were written. As part of the experimental verification of the imaging technique a mechanical raster scanning system was designed to cover a flat planar area while electronically sampling both the phase and amplitude of the ultrasonic diffraction pattern of various objects in the laboratory environment. When assembled in the future this data acquisition system will provide experimental verification of the results obtained in previous studies from computer simulated objects.

Publications: J. P. Powers, "Computer Simulation of Scalar Linear Acoustic Diffraction," Acoustical Holography, Vol. 7, Lawrence Kessler, Ed., Plenum Press, New York.

Title: Magnetic Background Noise Studies

Investigator: George L. Sackman, Associate Professor of Electrical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: The long-term objective of this study is to characterize the spectral density, amplitude probability density, and spacial cross-correlation of magnetic background noise. The immediate objective is to establish a magnetometer data acquisition system capable of recording simultaneous measurements of total field, vector field, and field gradient at several locations in a form suitable for analysis by digital computer. These studies are part of a continuing program to agument Navy system R&D in magnetic detection and degaussing of submarines.

Summary: This study is in its initial phase and the major effort during the period covered by this report was devoted to re-establishing a magnetic observatory site, using the NPS Cesium magnetometer. A data acquisition system based on direct measurement of the Larmor period was developed which has a response time less than 2.5 milliseconds. However, noise introduced by the FM tape recording system limited resolution to 0.3 gamma. An improved system using digital tape recording is being developed.

Thesis Directed:

LT C. L. Xefteris, USN, "A Magnetometer Data Acquisition System," Master's Thesis, June 1976.

Title: Range Studies -- Non-acoustic Sensors

Investigators: G. L. Sackman, Task Group Leader, Associate Professor of Electrical Engineering
M. H. Bank, Assistant Professor of Aeronautics
D. B. Hoisington, Professor of Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: The overall objective of this study has been to consider the implications of the forthcoming Trident facility on non-acoustic services which Naval Torpedo Station might be called upon to provide.

Summary: The immediate objective is to survey the area of magnetic silencing (deperming/degaussing) and potentially available magnetic sensors suitable for a magnetic testing range. A review of the literature on deperming and degaussing has been written, and an annotated bibliography compiled. The state of art in magnetometers has been assessed, including visits to instrument manufacturers, and candidate sensors for magnetic range use have been examined.

Publications: O. B. Wilson (Editor), "Range Study Program, Annual Summary Report," NPS-71W176081, August 1976.

Title: Seawater Properties that Cause Scattering and Absorption of the ORIC System Light Beam

Investigator: Donald A. Stentz, Associate Professor of Electrical Engineering

Sponsor: Naval Air Development Center

Objectives: The objectives of this task were to: a. Locate and Catalog sources of optical scattering data for various kinds of seawater. b. Study the relationship of optical scattering to temperature profile, and other properties of the first 300 meters of the water column, and determine the validity of these relationships for predicting location and magnitude of optical scattering as it concerns the ORIC system. c. Determine the variability in terms of both spatial and temporal characteristics. d. Suggest a format for presentation of optical scattering data, and initiate an OEICS scattering atlas.

Summary: The literature concerned with the propagation of visible light through seawater has been reviewed. Much of this research, both theoretical and in situ measurements, have been carried out at wavelengths close to that of ORICS. Of particular interest is the absorption and scattering characteristics of seawater due to dissolved organic matter, chemical content (salts), temperature variations, and suspended particulates of all descriptions. This search has revealed a growing number of reports concerned with the determination of the scattering of light, both natural and artificial, when viewed from above the surface of the ocean. The principle thrust of this work is to find a satisfactory model of the water path from which a measure of the light radiated from the surface will correctly indicate the optical characteristics of the water column, and indirectly indicate the presence or abscence of certain kinds of dissolved organic matter, organic and inorganic suspended matter, and perhaps even temperature variations of the water column.

Investigators of the optical properties of the ocean have suggested at least four analytical approaches to approximate the absorption and scattering of radiant flux that

impinges upon the surface of a flat ocean. The incident light energy is thought to arrive normal to the surface for purposes of ORICS, however, these investigators used direct sunlight, sky light, and various kinds of artificial light including the laser which may arrive at any angle. Their sensors were designed to accept light from all direction on a Lambert surface. The four approaches taken by these investigators are: a. Multiple integration using the volume-attenuation and scattering coefficients of the water column. b. Radiative Transfer. A method using iterative computation and intergo-differential equations. This method seems to be the most promising. c. Monte Carlo computational procedures. This approach, as well as the radiative transfer approach use Mie and/or Rayleigh scattering functions to determine the angle of scatter for each photon collision. d. Diffusion theory.

The particular interest in the examination of each approach was to obtain at least an intuitive feeling for the water parameters that affect the propagation (absorption and scatter) of the photon as it travels between light source and sensor. The reflection characteristics of the target were not considered at this time. A number of interesting conclusions can be made from these models. None of the approaches perfectly model the water column, however tests made by the researchers indicate that some of the methods are reasonably accurate if certain things are known about the water column such as the type of water, depth, mixing, temperature, etc.

Future work will include an examination of various types of seawater in regard to chemical content, absorption and scattering coefficients, size and characteristics of suspended particulate matter, and temperature variations that appear to have an influence on the ORICS light beam. The spatial and temporal variation will be studied as well. It the laser light is modulated in intensity by these natural parameters of the water column, then perhaps the ORIC system can be used as a search instrument where the natural characteristics of the column

have been shifted, mixed, or otherwise adjusted by the passage of a submarine. If one of these models can be used as the signal processing approach, the ORIC system may also be useful as an oceanographic instrument.

Further work on this project has been discontinued because of funding, however a final report is nearly completed which will summarize the literature search and the optical absorption and scattering of the ORICS light beam.

Publications:

Donald A. Stentz, "A Chronological Study of the Measurement of the Optical Properties of Ocean Water; and an Atlas of the Diffuse Attenuation Coefficient, K, of Tropical Atlantic Ocean Waters," Technical Report NPS-52Sz75061, June 1975.

Title: Application of Recursive Comb Filter to MTI Radar Signal Processing

Investigator: T. F. Tao, Associate Professor of Electrical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: To investigate the feasibility of using recursive comb filter as the canceller of a MTI radar.

Summary: When a recursive filter uses delay devices of N delay stages, its frequency characteristics have a comb feature with a period of fs/N where fs = sampling frequency. By properly designing the feed forward and the feedback coefficients, the comb filter characteristics can be made to have high attenuations at a series of periodically spaced frequencies at d.c. and the multiples of fs/N and good transmission in between. If fs/N is matched to the pulse repetition frequency of a radar, this type of comb filter can be used as the canceller in a MTI radar. However, additional requirements must be met for bandwidth consideration. Altogether, three relations should be satisfied:

Canceller requirement = fs/N = PRF

Bandwidth requirement = $BW \geq \frac{1}{2\tau}$

Sampling frequency requirement = $fs \geq 2BW = \frac{1}{\tau}$

where τ = radar pulse width

BW = electronic bandwidth

Several canceller type of comb filters have been studied both experimentally and theoretically using two types of delay lines: 8 bits CCD and 96 bits CTD delay lines. However, their bandwidth is not adequate for real MTI radar applications. Instead, simulated MTI radar signals with less demanding bandwidth requirement were used to investigate the feasibility of using this type of comb filter as cancellers.

The result is encouraging and is reported in the following paper. Further investigation is being continued because a new CCD of better bandwidth and long enough delay time recently became available (although its dynamic range is more limited).

Publications: T. F. Tao, V. Iamsaad, S. Holmes, B. Freund, L. Saltre and T. Zimmermann, "Sampled Analog CCD Recursive Comb Filter," Proceedings of 1975 International Charge Coupled Device Applications Conference, San Diego, CA, October 1975, pp. 257-266.

Theses Directed:

L. T. Saetre, "Sampled Analog Recursive Comb Filters and Their Application to MTI Radar," Master's Thesis, December 1975.

S. V. Holmes, "Theory of Operation and Applications of Sampled Analog Devices in Recursive Comb Filters," Ph.D. Thesis, June 1976.

Title: Sampled Analog Signal Processing and IV - VI MIS Study

Investigator: T. F. Tao, Associate Professor of Electrical Engineering

Sponsor: Naval Electronics System Command

Objective: (1) To develop the theory and design procedure of recursive filter using charge transfer devices.

(2) To develop high dielectric constant insulator fabricated by a low temperature process compatible with non-silicon semiconductors.

Summary: (1) Sampled analog signal processing using CTD devices are generally similar to digital signal processing but with some significant differences. This study is concerned with the CTD recursive comb filters. Two design procedures have been used. One is indirect which first designed a transfer function H(S) using the well developed analog filter theory and then transforms H(S) into H(Z) for implementation using CTD devices. The other is direct which obtains a transfer function H(Z) directly from a specified frequency domain requirement. Several filters designed by these procedures were studied both experimentally and theoretically. It was found that the digital recursive filter theory must be significantly modified to explain the experimental behavior of sampled analog recursive filters. The major differences are the frequency dependence of the filter coefficients and the multiple delay stages of the delay line.

(2) High dielectric constant insulator is of interest in the fabrication of Metal-Insulator Semiconductor devices of IV-VI semi-conductors for infrared charge coupled imaging applications. Because the material limitations of these IV-VI semiconductors, fabrication process can not exceed 300-500°C. During this period, an electrolytic anodization process has been used to make tantulum oxide, a high dielectric constant insulator. Si of both n type and p type have been used to develop this process. Encouraging results have been obtained which will be reported in detail upon the completion of an engineer's thesis in December 1976.

Publications:

T. F. Tao, V. Iamsaad, S. Holmes, B. Freund, L. Saetre and T. Zimmermann, "Sampled Analog CCD Recursive Comb Filter", Proceedings 1975 International Charge Coupled Device Applications Conference, San Diego, California, October 29-31, 1975, pp 275-266.

T. F. Tao and S. Holmes, "Hardware Signal Processor Development--Session Summary" Proceedings Ninth Asilomar Conference on Circuits, Systems and Computers, November, 1975, Asilomar, California, pp 289-299.

Theses Directed:

S. V. Holmes, "Theory of Operation and Application of Sampled Analog Devices in Recursive Comb Filters," PhD. Thesis, June 1976.

M. Ang Vong, "Study of an Integrated Circuit Tapped Delay Line and its Applications to Signal Processing," Master's Thesis, June 1976.

Title: Analytical Studies of Captured Air Bubble Type Surface Effect Ships

Investigator: G. Thaler, Professor of Electrical Engineering

Sponsor: Naval Sea Systems Command

Objective: To validate and update the Digital Simulation Program developed by Oceanics, Inc. To develop techniques for applying this program to predict the dynamic behavior of a variety of captured air bubble boats including the XR-3, as well as extension to a 2000 ton size. To study problems of scaling habitability, dynamics and control which are of importance for future developments.

Summary: Validation studies of the XR-3 program led to updating, studies of plenum pressure dynamics, and preliminary studies of the effect of introducing a membrane in the plenum wall (deck). Parallel studies of the frequency response of the XR-3 have led to good correlation with sea state behavior and better understanding of basic principles.

Current studies include investigation of minimizing power consumption by control of plenum pressure and pitch angle. Studies of sealing problems are also being carried out, with particular attention to the interpretation of towing tank data in terms of full size ships.

Theses Directed:

Boggio, J. M., "A Study of Pressure-Volumn Rates and Plenum Membrane Additions to the Captured Air Bubble Surface Effect Ship XR-3 Digital Computer Loads and Motion Program," Master's Thesis, June 1976.

Booth, B. F. III, "The Frequency Response and Operating Characteristics of the XR-3 Loads and Motions Program," Master's Thesis, June 1976.

Menzel, R. F., "Study of the Roll and Pitch Transients in Calm Water Using the Simulated Performance of the XR-3 Surface Effect Ship Loads and Motions Computer Program, " Master's Thesis, December 1975.

Title: Torpedo Tracking

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Torpedo Station

Objective: The application of Kalman filtering to torpedo range tracking made in the location of sensor arrays.

Summary: The application of Kalman filtering to the on-line real-time tracking problems at Keyport as well as for improving the post-run data analysis is underway. Two thesis students are involved in the project. A workshop on Kalman filtering has been presented to engineers at keyport. A tape of a Mark 48 torpedo track has been obtained and is presently being used to check out our computer tracking algorithm for this application. Two computer programs have been implemented on the Naval Torpedo Station computers and a briefing has been given to their possible users. The software was presented with a summary of the two thesis projects which were completed this December. Work is continuing on this project and a report will be presented in June.

Publications: None

Title:	Naval Applications of Scanning Processor
Investigator:	H. A. Titus, Professor of Electrical Engineering
Sponsor:	Naval Electronic Systems Command
Objective:	To develop optimal techniques for scanning, target tracking, and pattern recognition in the application of CCD and CID devices to target tracking.
Summary:	A study is being made of the optimal scanning techniques for target tracking, and pattern recognition in the application of CCD and CID devices to target tracking. A study is also being made of the optimal scanning techniques for target tracking in a two-dimensional field and for the optimal tracking thereof. Techniques for integration of pattern recognition schemes and target tracking algorithms are being looked at and a computer simulation is being developed. In addition, coherence functions are being developed having two-dimensional axes of time delay and doppler and the tracking of significant parameters in this two-dimensional plane is being addressed. This work is just getting underway. One thesis student is involved in this image processing effort.
Conference Presentation:	H. A. Titus and M. Schacher, "Image Processing Algorithms for IR Target Tracking," presented at Asilomar Conference on Circuits and Systems Monterey, California, November 1976.
Publications:	None

Title: Coherent and Incoherent Tracking and Undersea Surveillance

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Electronic System Command

Objective: It is our intent to demonstrate several techniques for coherent and incoherent acoustic tracking for both the near field problem (P3C) and for long-range applications.

Summary: The program for submarine tracking using extended Kalman filtering with single difar buoy or multiple buoys was previously developed for incoherent signals. This work has been extended to cover this potentiality coherent signal. A study has been made of the initialization problems involved therein. Three thesis students have completed work in this program.

Conference Presentations: H. A. Titus, D. E. Kirk and G. Mitschang, "Locating with Fixed Sensor Having Observations of Signal Angle of Arrival and Doppler Shifted Frequency," presented at Sixth Symposium on Nonlinear Estimation Theory and its Applications, San Diego, California, September 1975.

H. A. Titus and D. E. Kirk, "Evaluation of Linear Estimation for Nonlinear Systems," presented at Asilomar Conference, Monterey, California, November 1975.

Title: Computer Program Improvements for the Laser Gyro Application in a Medium Range Missile

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Weapons Center

Objective: This study is to improve upon the Kalman filtering algorithm presently proposed for a laser-gyro system under study at the Naval Weapons Center.

Summary: A thesis student has begun work on the Kalman filter program for the optimal reset of a laser gyro with updating. An attempt here is being made to improve upon the algorithms developed for inflight updating of strap-down inertial mid-course guidance systems in the work by Gregory Nazarof of the Weapons Development Department at China Lake. The thesis student developed the simulation and completed his work in December. A second student is starting work in this area and will continue his work at the Draper Laboratories at MIT. This work is presently unfunded.

Publications: None

Title: Integrated Aircraft Maneuver and Jamming for Missile Evasion

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Air Systems Command

Objective: This study involves the optimal use of jammers for missile evasion as well as the integration of optimal maneuvers.

Summary: Funding for this project was received on June 26, 1976, and work is presently in progress. Several simulations are being developed to evaluate optimum jamming techniques against specific missiles. The modulation schemes involved in the servo tracking loops of the sensors are being investigated. The sensitivity of several AGC circuits and doppler tracking circuits are being studied. In addition, optimal control theory is being applied to attempt optimal maneuvers to avoid the missile. A Ph.D. candidate student is involved in this project. Included in this study will be investigations of home on jam, AGC gate capture, velocity gate pull-off, angle gate steal, and J to S requirements for expendable and on-board jammers.

Conference Presentations: H. A. Titus with D. B. Hoisington, "Electronic Warfare and Missile Design," presented at the Naval Tactical Missile Colloquium, 20-30 April, 1976, Naval Postgraduate School, Monterey, California.

Title: Mission Planning for EA6B

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Air System Command

Objective: To devise computer-aided display programs for utilization in mission planning in EA6B.

Summary: Two thesis students are presently developing a computer program to handle mission planning problems involving hostile radar, missile and gun placement. An EOB is placed in the computer and a computer search is made for optimal tracks to maximize the effectiveness of the EA6B's jammers. A program will indicate on the display the reduced radar environment due to jamming and give quantitative measures of potential effectiveness. Through the display the operator may interact with the system to improve upon the computer's solution and through a process of evolution, optimum mission plan for EA6B support will evolve. A hard copy of mission profiles and stand-off regions will be the output from the program. The first student thesis work will be published in June of 1977.

Publications: None

Title: Position Locating Reporting System

Investigator: H. A. Titus, Professor of Electrical Engineering

Sponsor: Naval Electronic Systems Command

Objectives: Kalman filtering techniques are applied to the Position Locating Reporting System involving many radio transponders ranging on each other in a computer controlled enviornment.

Summary: In the PLRS system a master computer will keep track of some 350 radio transmitter-receiver units which may be placed in helicopters, aircraft, tanks, and with troops. The essential mechanism for locating is obtained by pulse transient time. Because of obvious problems to be encountered with terrain, the computer may connect to a unit which it desires to locate via several units. These units would act as relay units in the transferral of time pulses. In addition, in order to obtain an initial location, several units are required to be in contact with the unit to be located all via the computer. When a unit location is to be updated, the computer must determine which units it wishes to make contact through to obtain an optimum reduction in the covariance of error associated with the location of the unit in question. The problem is complicated additionally by the fact that these relay units themselves have uncertain location with associated covariance of error in position.

A simulation was performed involving an aircraft in a 3g turning maneuver and several ground relay stations. An effective algorithm was developed for the choice of which relay station is to be used. This simulation is now being extended to handle a multitude of ranging units each with appropriate dynamics and associated covariances of error in their position location.

Publications: H. A. Titus and C. A. Ditmar Jr., "The Application of Extended Kalman Filtering to the Position Locating Reporting System (PLRS)," Technical Report NPS-52Ts-75121, December 1975.

Title:	Nonlinear Sources of Harmonics in Power Line Voltages and Currents
Investigator:	M. Wilcox, Associate Professor of Electrical Engineering
Sponsor:	Naval Ship Engineering Center
Objective:	Not well defined as yet but in general seems to be to determine what can be done to recognize and correct harmonies in the power lines due to nonlinear electromagnetic devices.
Summary:	As indicated in the objective, this is in the planning stage. Again literature searches are being made, preparatory work in the laboratory is being done depending on availability of appropriate equipment. A proposal has been submitted but no action taken as yet.
Publications:	None

Title: Dynamic Braking of Ships

Investigator: M. Wilcox, Associate Professor of Electrical Engineering

Sponsor: Naval Ship Engineering Center

Objective: To investigate the possibility of recovering and storing some of the ships kinetic energy when stopping a ship.

Summary: Since funding is unknown, the project is still in the beginning stage. So far information gathering is being attempted, appropriate literature searches are being made, equations of motion are being established and initial programming is being done.

Publications: None

DEPARTMENT OF METEOROLOGY

The research program in the Department of Meteorology has continued along several main lines as follows: (1) Numerical weather prediction, (2) Analysis and dynamics of tropical weather systems, (3) Marine boundary-layer turbulence, (4) Tropical cyclone prediction, (5) Marine fog observation and prediction. Under each of these headings, a number of related investigations are being pursued by various faculty members, as described briefly below.

NUMERICAL WEATHER PREDICTION

Under this heading are included: modeling of the large-scale weather systems by G. J. Haltiner and R. T. Williams; numerical prediction of ocean-hurricane interaction by R. L. Elsberry; ocean circulation modeling and prediction by R. L. Haney; solar and terrestrial transfer simulation by F. L. Martin; and boundary-layer parameterization by K. L. Davidson.

ANALYSIS AND DYNAMICS OF TROPICAL WEATHER SYSTEMS

C.-P. Chang, R. L. Elsberry and R. T. Williams are investigating various aspects of the dynamics of tropical weather systems, including development of hurricanes and typhoons by Elsberry, the dynamics and energetics of tropical wave disturbances and circulations by Chang and Williams, and the diagnostic analysis of tropical systems by Chang.

MARINE BOUNDARY-LAYER TURBULENCE AND TURBIDITY

This research area includes K. L. Davidson's observational studies of the air motion induced by ocean waves and its relation to boundary fluxes, and boundary-layer simulation for numerical weather prediction models. Turbulence plays an important role in the vertical transport of momentum, heat and water vapor which are essential processes in weather prediction. K. L. Davidson, in collaboration with other Naval Postgraduate School faculty, is involved in an interdisciplinary study of turbulence and aerosal effects on optical propagation in the marine boundary layer. This study includes observational experiments to obtain descriptions of the vertical distribution of small scale turbulence or properties which affect optical propagation and aerosal distributions.

TROPICAL CYCLONE CLIMATOLOGY PREDICTION

The climatology and prediction of movement of eastern North Pacific tropical cyclones has been pursued by R. J. Renard and J. D. Jarrell. The developed analog prediction technique, EPANALOG, is now being used operationally.

MARINE FOG OBSERVATION AND PREDICTION

An interdisciplinary project, involving R. J. Renard and K. L. Davidson, Department of Meteorology, and faculty members from the Departments of Oceanography, and Physics and Chemistry, is concerned with the observation, climatological analysis, and prediction of fog over open ocean and coastal regimes, both on a regional and hemispheric scale.

Title: Tropical Wave Dynamics

Investigators: C.-P. Chang, Assistant Professor of Meteorology
R. T. Williams, Professor of Meteorology

Sponsor: National Science Foundation

Objective: To study the dynamics of large-scale wave motions in the tropical troposphere and lower stratosphere in terms of theoretical interpretation of their development, maintenance and structure and the inter-relationship between them.

Summary: Many aspects of tropical waves are included in this study, but the present emphasis is on the excitation mechanisms of the various types of waves. The main results obtained so far include: 1) selection of stratospheric Kelvin waves can be explained by randomly-distributed heat sources in the troposphere; 2) wave-CISK (instability due to internally-induced cumulus heating) would give rise to very small growth rates and large vertical wavelengths; 3) inclusion of viscous damping comparable to that derived from observational studies would alter the equatorial wave theory greatly for slowly-moving waves, and can explain the basic character of the tropospheric waves; 4) first order effect of a mean flow with varying barotropic instability depends on the relative contributions of several advective terms; and 5) CISK will not greatly alter the barotropic instability selection mechanism.

Publications:

C.-P. Chang, "Vertical Structure of Tropical Waves Maintained by Internally-Induced Cumulus Heating." Journal of Atmospheric Sciences, Volumn 33, 729-739, 1976.

C.-P. Chang, "Forcing of Stratospheric Kelvin Waves by Tropospheric Heat Sources." Journal of Atmospheric Sciences, Volumn 33, 1976.

C.-P. Chang, "Comments on Instability Theory of Large-Scale Disturbances in the Tropics." Journal of Atmospheric Sciences, Volumn 33, August 1976.

C.-P. Chang and R. T. Williams, "Barotropic Instability of a Spatially-Varying Mean Flow." Presented at the Conference on Atmospheric Waves and Stability, Seattle, March-April 1976. Abstract published in Bulletin of American Meteorological Society, 57, 1976.

C.-P. Chang, "Viscous Internal Gravity Waves and Low-Frequency Tropical Oscillations." Presented at Tenth Technical Conference on Hurricanes and Tropical Meteorology, Charlottesville, VA, July 1976. Abstract published in Bulletin of American Meteorological Society, 57, 1976.

Title: Numerical Simulation of Monsoon Circulations

Investigator: C.-P. Chang, Assistant Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: To simulate planetary-scale circulations and associated synoptic-scale wave disturbances in a global numerical model and to study the scale interactions.

Summary: This study focuses on two aspects of the monsoonal circulation during Northern Summer: the dynamics of the synoptic-scale wave disturbances generated by the instability of zonal-mean and planetary-scale flows in the upper trosposphere, and the simulation of the planetary- and synoptic-scale motions of the monsoon in a numerical model. The first part is studied as a theoretical problem by treating the linearized barotropical vorticity equation both analytically and numerically. The results are compared to those obtained from the second part, in which a numerical model essentially similar to the UCLA general circulation model is used, but presently the study involves specified heating only. Testing of fully parameterized heating will be continued in the following year.

Conference Presentations: C.-P. Chang, R. T. Williams and J. B. Tupaz, "Study of Planetary and Synoptic-Scale Waves of the Northern Summer Monsoon." Presented at the GARP Study Conference on tropical numerical modeling, Exeter, England, April 1976.

Title: Interannual and Spatial Variation of Tropical Waves

Investigator: C -P. Chang, Assistant Professor of Meteorology

Sponsor: National Environmental Satellite Service, National Oceanic and Atmospheric Administration

Objective: The structure and properties of the tropical easterly waves have been found to vary considerably between different regimes and time periods. This study investigates the possible roles played by the temporal and spatial sea-surface temperature (SST) variations on the waves using radiosonde and satellite data and a tropical objective-analysis data set.

Summary: Time series of tropical western Pacific radiosonde data during two contrasting eight-month periods of SST anomalies, May-December 1972, which has abnormally high SST in the central and eastern Pacific, and May-December 1973 which has below normal SST in the same region, have been analyzed. In both periods, the waves have the same periodicity of 4-5 days and a lower tropospheric zonal wavelength on the order of 3300 km, but their vertical phase and amplitude distributions as well as the thermal structures are different. The results are discussed in terms of two possible influences the SST variations may have on the waves: 1) direct effect, the warmer SST represents stronger thermal control through cumulus heating; and 2) indirect effect, the variation of SST changes the large-scale mean wind circulation which, in turn, has a strong impact on the wave vertical structure and the relative importance of energy sources other than cumulus heating. A schematic model of these influences was proposed which may be applied to both the temporal and the spatial variations of SST. Continuation of this work using satellite data is planned for next year.

Publications: C -P. Chang and C. R. Miller, III, "Spectrum Analysis of Easterly Waves in the Western Pacific During Two Contrasting Periods of Sea-Surface Temperature Anomalies," Fall Annual Meeting of American Geophysical Union, San Francisco, December 1975. Abstract published in Transactions, 57, 997, 1975.

C -P. Chang and C. R. Miller, III, "Spectrum Analysis of Easterly Waves in the Tropical Pacific During Two Contrasting Periods of Sea-Surface Temperature Anomalies," Technical Report NPS-63Cj76071, July 1976.

C -P. Chang and E. Maas, Jr., "A Case of Cross-Equatorial Displacement of a Vortex," Monthly Weather Review, Volumn 104, 1976.

Title: Tropical Wave Dynamics

Investigators: C -P. Chang, Assistant Professor of Meteorology and R. T. Williams, Professor of Meteorology

Sponsor: Foundation Research Program (6.1)

Objective: To study the dynamics of large-scale wave motions in the tropical troposphere and lower stratosphere in terms of theortetical interpretation of their development, maintenance and structure and the inter-relationship between them.

Summary: Many aspects of tropical waves are included in this study, but the present emphasis is on the excitation mechanisms of the various types of waves. The main results obtained so far include: (1) selection of stratospheric Kelvin waves can be explained by randomly-distributed heat sources in the troposphere; (2) wave-CISK (instability due to internally-induced cumulus heating) would give rise to very small growth rates and large vertical wavelengths; (3) inclusion of viscous damping comparable to that derived from observational studies would alter the equatorial wave theory greatly for slowly-moving waves, and can explain the basic character of the tropospheric waves; (4) first order effect of a mean flow with varying barotropic instability depends on the relative contributions of several advective terms; and (5) CISK will not greatly alter the barotropic instability selection mechanism.

Publications: C-P. Chang, "Vertical Structure of Tropical Waves Maintained by Internally-Induced Cumulus Heating," Journal of Atmospheric Sciences, 33 729-739, 1976.

C -P. Chang, "Forcing of Stratospheric Kelvin Waves by Tropospheric Heat Sources," Journal of Atmospheric Sciences, 33, 740-744, 1976.

C -P. Chang, "Comments on Instability Theory of Large-Scale Disturbances in the Tropics," Journal of Atmospheric Sciences, 33, August 1976.

C -P. Chang and R. T. Williams, "Barotropic Instability of a Spatially-Varying Mean Flow," presented at the Conference on Atmospheric Waves and Stability, Seattle, March-April 1976. Abstract published in Bulletin of American Meteorological Society 57, 1976.

C -P. Chang, "Viscous Internal Gravity Waves and Low-Frequency Tropical Oscillations," presented at the Tenth Technical Conference on Hurricanes and Tropical Meteorology, Charlottesville, VA, July 1976. Abstract published in Bulletin of American Meteorological Society, 57, 1976.

Title: Meteorological Effects on Optical Propagation in the Marine Boundary Layer

Investigator: K. L. Davidson, Associate Professor of Meteorology

Sponsor: Naval Sea Systems Command

Objective: The long range objective of this research is to develop methods for predicting optical propagation properties in the marine boundary layer on the basis of its bulk properties, e.g., wind speeds and air-water temperature differences. The short range objective is to obtain observational descriptions of coincident turbulent and mean properties, wind and temperature, from the sea surface to 1km and also aerosol distribution. This is a continuing project.

Summary: A specific goal of this study is to relate small scale turbulent and aerosol properties to the mean hydrostatic stability. Such stability is definable from measures of the surface wind speed and the near surface air-water temperature difference. Small scale turbulent properties are expected to vary differently with height under different conditions of stability. Results from multi-level shipboard and kiteborne measurements under several conditions of stability reveal distinct differences in height variations of the small-scale parameters under different conditions of stability. The observed height dependencies approximate those predicted on the basis of over-land investigations. The variations from the predictions will be examined for possible wave influence when more data become available.

Publications:

K. L. Davidson, "Descriptions for Wind Profiles and Wind Fluctuation (gust) Statistics Over Ocean Waves," Handbook for Offshore Port Planing, Marine Technology Society, September 1974.

K. L. Davidson and T. Houlihan, "Laser Propagation in the Marine Boundary Layer," Proceedings of the Ordnance Hydroballistics Activities Committee Meeting, Newport, R. I., October, 1974.

K. L. Davidson and T. Houlihan, "Laser Transmission in the Marine Environment." Accepted for publication in Naval Engineers Journal.

K. L. Davidson and T. Houlihan, "Optically Relevant Turbulence Parameters in the Marine Boundary Layer," Proceedings 13th Annual SES Meeting, Nov 1976, NASA-Langley Research Center, Hampton, VA 15 pages (in press).

K. L. Davidson and T. Houlihan, "Turbulence Effects upon Laser Propagation in the Marine Boundary Layer," Proceedings of SPIE, Imaging through the Atmosphere, Mar 22-23,1976, Reston, VA.

K. L. Davidson and R. J. Stricker, "Temporal Variations and Spectral Properties of Wind and Temperature near the Surface over the Tropical Ocean," Boundary-Layer Meteorology, 1976. Accepted for publication.

Title: Tropical Cyclone Studies

Investigator: R. L. Elsberry, Associate Professor of Meteorology

Sponsor: Naval Environmental Prediction Research Facility

Objective: This research is part of a continuing, cooperative effort to develop an operational, dynamic forecast model for typhoons in the western North Pacific region.

Summary: Based on a review of the status of nested grid and limited region numerical models, the development of an operational tropical cyclone prediction model was initiated in cooperation with other Navy research and operational units. An existing triply nested numerical model was used to demonstrate the feasibility of forecasting typhoon movement using hand-analyzed data. For this special case, the numerical model forecasts were considerably better than the official motion forecasts. An improved method of initializing such a nested grid model has been devised to avoid the requirement for very fine scale data throughout the region, and yet permit a smooth evolution of the flow near the interfaces between grid meshes. The model is being tested on a quasi-operational basis at Fleet Numerical Weather Central during the 1976 typhoon season. In addition, a research version is being tested at NEPRF on a large number of cases from the 1975 season.

Conference Presentations: Elsberry, R. L., "Developmental Experiments for a Western Pacific Tropical Cyclone Forecast Model." Presentation at Joint Organizing Committee Study Conference on the Development of Numerical Models in the Tropics, Exeter, England, 4-10 April 1976.

Publications: Elsberry, R. L., and G. W. Ley, "On the Strategy of Initializing Nested Grid Meshes in Numerical Weather Prediction." Monthly Weather Review, 104, June 1976.

Elsberry, R. L., R. Perry and D. Hinsman, "Experiments With a Nested Grid Model for Tropical Cyclone Motion Forecasts." Pre-print Joint DMG/AMS International Conference on Simulation of Large-scale Atmospheric Processes, Hamburg, Germany, September 1976.

Elsberry, R. L., "Feasibility of an Operational Tropical Cyclone Prediction Model for the Western North Pacific Area." Technical Report NPS-51Es 75051, May 1975.

Thesis Directed: Ley, G. W., "Some Design Experiments for a Nested Grid Forecast Model of Western Pacific Tropical Cyclones," Master's Thesis, September 1975.

Title: The Oceans and Severe Tropical Storms

Investigators: R. L. Elsberry, Associate Professor of Meteorology
D. F. Leipper, Professor of Oceanography

Sponsor: Office of Naval Research

Objective: The long-range scientific objective of this project is to describe the effect of severe tropical cyclones upon the surface layers of the oceans through a coordinated numerical modeling and data collection effort. We hypothesize that significant large-scale changes in new-surface oceanic parameters occur during periods of intense forcing due to passage of tropical cyclones. Thus the potential improvement in analysis and predictive capability for near-surface oceanic parameters could have an important impact on environmental support for fleet operations in the tropical oceans.

Summary: The first phase of the modeling effort was to develop an interacting hurricane-ocean model capable of simulating the surface heat and momentum fluxes (Elsberry, Pearson and Corgnati, 1974, J. Geophys. Res.). Next an oceanic mixed-layer model was developed to predict the thermal response in the ocean (Elsberry, Fraim and Trapnell, 1976, J. Geophys. Res.). Recently the oceanic model has been improved through the use of the hydrodynamic equations to predict the layer-mean currents, and thus the upwelling of the thermocline. The objective is to predict the different mode of response over a range of tropical cyclone displacements and intensities. One of the primary results of the modeling effort has been to illustrate the important role of thermally and mechanically generated turbulence in cooling and deepening the mixed layer. The production of an intermediate warmer layer due to downward heat flux at the base of the mixed layer is simulated in this model and is found in the observations. Furthermore the horizontal distribution of mixed-layer depth simulated by this model is more realistic than in previous models. Inclusion of the hydrodynamic equations has produced a simulation of an oscillatory response in mixed-layer depth in the wake of fast-moving storms that is similar to observations and linear theory. Some of these results have been summarized in a review article (Elsberry, 1975).

Since the best ship data on hurricane-ocean interaction must cover a time period of several weeks

and cannot provide a true synoptic picture of shorter period changes, we set out to obtain observations by aircraft. Through a combination of careful planning, fleet cooperation and fortunate circumstances, CDR William Schramm was able in 1975 to obtain three sets of oceanic data associated with typhoon Phyllis. A pattern of bathythermograph observations was repeated three times; once immediately before the typhoon passage, once immediately after and once 48 hours later. Sixty-seven soundings were obtained providing the best synoptic coverage to date in such a situation. The analysis of these data is continuing.

Publications:

Camp, N. T. and R. L. Elsberry, "Vertical Heat Fluxes Associated with the Deepening Mixed Layer During the Cooling Season." (Abstract) Bulletin American Meteorological Society, 57, 135, 1976.

Elsberry, R. L., et al., "Numerical Simulation of Ocean Thermal Response to Hurricane Passage." (Abstract) Bulletin American Meteorological Society, 56, 1975.

Elsberry, R. L., T. S. Fraim, and R. N. Trapnell, Jr., "A Mixed-layer Model of the Oceanic Thermal Response to Hurricanes." Journal Geophysical Research, 81, 1976.

Schramm, W., "Ocean Thermal Response to the Passage of Typhoon Phyllis." (Abstract) Bulletin American Meteorological Society, 57, 1976.

Title: Primitive Equation Model Initialization by a Variational Method

Investigators: George J. Haltiner, Professor of Meteorology
Edward H. Barker, Naval Environmental Prediction Research Facility (NEPRF)

Sponsor: Naval Environmental Prediction Research Facility

Objective: To produce global balanced wind and mass fields for initializing a primitive equation numerical weather prediction model.

Summary: A variational method is used to adjust objectively-analyzed wind and geopotential fields using the balance equation as a strong constraint. The resulting Euler-Lagrange equations are simpler on p-surfaces than on σ-surfaces; hence the initial experiments have been carried out on p-surfaces. After interpolating the data to σ-surfaces, the data are rebalanced on the σ-surfaces with the aim of suppressing the inertial-gravity noise normally generated in the early stages of a numerical forecast. The method has been shown to be successful in suppressing noise in an adiabatic two-level version of the Arakawa-Mintz general circulation model without mountains. Further experiments are now in progress with a five-level model with mountains. The next step will be to carry out the variational procedure directly on σ-surfaces to avoid the need for rebalancing. A comparison will be made of accuracy and required computer time for the two methods.

Publications:

Haltiner, G. J., E. H. Barker and Y. K. Sasaki, "An Initialization Technique for Primitive Equation Models Using a Balance Equation Technique". Proceedings of the GARP Joint Organizing Committee Study Group Conference on Four-Dimensional Data Assimilation, Paris, France, November 17-21, 1976.

Haltiner, G. J. and E. H. Barker, "Initial Balancing with a Variational Method", Annalen Der Meteorologie, Neue Folge, Nr 11, 1976.

Title: The Numerical Simulation of the Coupled North Pacific Ocean-Atmosphere System

Investigator: R. L. Haney, Associate Professor of Meteorology

Sponsor: Office of Naval Research

Objective: The objective of this project is to continually develop and improve a numerical model of the North Pacific Ocean and to use the model to identify processes responsible for the formation and evolution of large-scale thermal anomalies.

Summary: The ocean model (Haney, 1974) has been improved to include time dependent seasonal forcing by the atmosphere; a parameterization of surface generated wind stirring and convective overturning (Haney and Davies, 1976); and nonlinear lateral eddy viscosity based on two-dimensional turbulence theory (Haney and Wright, 1975). A "model climatology" has been generated by integrating the ocean model over a long period of time (240 years) starting from a stratified initial state and using climatological seasonal forcing by the atmosphere. This model climatology is being combined with thermal anomalies to form the initial conditions for a number of initial value prediction experiments. These experiments examine and compare the evolution of large scale thermal anomalies having different vertical structures. The initial conditions for the anomalies consist of idealized thermal anomalies as well as actual anomalies observed within the NORPAX program. Anomaly prediction experiments using anomalous forcing by the atmosphere are also planned.

Conference Presentations: Haney, R. L., and K. L. Hunt, "Preliminary Experiments in the Numerical Prediction of Large-scale Sea Surface Temperature Anomalies." Presented at the Fall Annual Meeting of the A.G.U., Dec. 8-12, 1975, San Francisco.

Publications: Haney, R. L., and J. M. Wright Jr., "The Relationship Between the Grid Size and the Coefficient of Nonlinear Lateral Eddy Viscosity in Numerical Ocean Circulation Models." Journal of Computational Physics, 19, 1975.

Haney, R. L., and R. W. Davies, 1976: "The Role of Surface Mixing in the Seasonal Variation of the Ocean Thermal Structure." Journal of Physical Oceanography, 6 (in press).

Title: Climatology, Observation, Analysis and Prediction of Marine Fog

Investigator: R. J. Renard, Professor of Meteorology

Sponsor: Naval Air Systems Command

Objective: To improve the observation, climatology, diagnosis (analysis) and prognosis (forecasting) of marine fog over the open ocean and coastal areas.

Summary: The program has been divided into three phases: (a) climatology of marine fog frequencies, (b) observation and diagnosis (analysis) of marine fog, and (c) prognosis (forecasting) of marine fog. To date, mostly the first two phases have been researched; all stages are in various stages of completion.

Phase (a): The climatology of marine fog over the open ocean is considered to be poorly documented, and, with reference to a source widely used by the Navy, the climatology is incorrect. The Naval Postgraduate School (NPS) group has developed a unique approach to deriving marine fog frequencies by synthesizing the information content of the visibility-weather group elements of the marine synoptic report into a computerized specification of the percentage of the synoptic period experiencing fog.

Some 12 years of North Pacific ship-report data (over a half million reports, 30-60N) for the major fog season months of June, July, August and September have been processes to derive credible fog frequencies for each 1 x 1 degree lat/long square; the data are being further stratified to relate frequencies to wind direction and speed on 10 x 10 degree lat/long squares. As a prototype study, the results have universal application to all ocean areas. The National Climatic Center has already adopted, in part, the approach used here. The work continues.

Phase (b): Until such time that marine-fog areas can be initially specified accurately and completely, the forecasting of marine fog will remain primitive. Conventional ship data, at best sparse, are not adequate. Therefore, weather satellite observations (infra-red [IR] and visual) are being researched as a potential prime source of specifying areas of marine fog.

A statistical approach to identifying critical brightness (visual mode) and temperature (IR mode) count values associated with marine fog appears to have promise. Initially, digital NOAA-2 data for the North Pacific Ocean, July 1973, were computer processed, diagnosed and statistically compared to 3250 ship observations (ground truth) in the quest for a usuable empirical scheme. Current work involves the 5-9 August 1976 period in the eastern North Pacific, for which DMSP and SMS-2 digital data and imagery are being processed in context with conventional data, climatology and numerical statistical parameters in pursuit of an operationally useful approach to initialize areas of fog over the open ocean.

Phase (c): A successful means of forecasting marine fog by computer methods is, in part, dependent on (a) and (b) above, combined with the identification of marine-fog indices compatible with the model output parameters of Fleet Numerical Weather Central, Monterey, California.

This aspect of the program is in the state of identifying suitable atmospheric/oceanographic parameters for a MOS (model output statistics) approach to marine-fog forecasting, utilizing Fleet Numerical Weather Central as source for data and fields.

Conference Presentations:

R. J. Renard, "Marine-Fog Diagnosis and Climatology from Synoptic Weather Reports and Weather Satellite Observations over the North Pacific Ocean," presented at the NASC Fourth Conference on Marine Fog at the Laboratory of Atmospheric Physics, Naval Air Systems Command, Desert Research Institute, 6-7 January 1976, Reno, Nevada.

R. J. Renard, "A New Approach to the Determination of Climatological Marine Fog Frequencies with Application to the Summer Fog Season of the North Pacific Area," presented at the American Meteorological Society Second Conference on Ocean-Atmosphere Interactions 30 March - 01 April 1976, Seattle, Washington. (Abstract: Bulletin of the American Meteorological Society, Vol. 57, #1, January 1976.)

Publication: R. J. Renard, "The Observation, Analysis, Forecasting and Climatology of Marine Fog on the High Seas and in Coastal Areas; in World Meteorological Organizations," invited paper, published in Symposia Proceedings, WMO Technical Conference on the Applications of Marine Meteorology to the High Seas and Coastal Zone Development, Geneva, Switzerland,22-26 November 1976, Publication Number 454, 211-223 (1976).

Theses Directed: LT C. B. Ihli, Jr, "Use of DMSP and SMS-2 Visual/IR Satellite Data for Diagnosing Marine Fog over the North Pacific Ocean," Master's Thesis, 1976.

CAPT B. L. Van Orman, "A Statistical-Numerical Approach to Forecasting Marine Fog over the Open Ocean and Coastal Areas," Master's Thesis, 1976.

Title: Forecasting Motion of Tropical Cyclones in Eastern North Pacific Ocean by Statistical Means

Investigator: R. J. Renard, Professor of Meteorology
J. D. Jarrell, Assistant Professor of Meteorology

Sponsor: Navy Environmental Prediction Research Facility,

Objective: To develop a statistical analog scheme to forecast tropical cyclone motion in the eastern North Pacific Ocean area.

Summary: Fleet Weather Central, Honolulu, Hawaii, and the National Weather Service Forecast Office, at Honolulu, Hawaii, and Redwood City, California, are co-responsible for forecasting tropical cyclone activity in the North Pacific east of 180°. The area averages sixteen depressions, storms and hurricanes a year, occurring from mid May to mid November. To date, mostly subjective means have been used to forecast motion and intensity of these cyclones. A computerized, objective scheme was needed to improve the forecase accuracy as well as give a common starting point for the coordinated-agency forecast effort. The project resulted in the development of the Navy's Northeastern Pacific Analog Tropical Cyclone Tracker (EPANALOG) forecast program.

EPANALOG selects analog tropical cyclones from a 25-year Northeastern Pacific Ocean history. The selected anolog tracks, statistically adjusted for position, vector motion, and date differences between them and the recent history of the tropical cyclone being forecast, were composited into a single forecast track. Verifications of EPANALOG forecasts to 96 hours, as initiated from best-track positions, were determined for randomly selected historical cases with a Monte Carlo simulation of initial position inaccuracies, as well as for forecasts generated from 1973, 1974 and 1975 operational cyclone positions. The latter were intercompared with a homogeneous set of objective persistence and Modified Hurricane and Typhoon Tracking (MOHATT) forecasts as well as subjective OFFICIAL forecasts for the 24-, 48- and 72-hour intervals.

1973-1975 EPANALOG accuracy generally excelled that of the existent techniques for all forecast intervals tested. Work has generally terminated except for preparation of a final set of evaluation statistics.

Publication: J. D. Jarrell, C. J. Mauck and R. J. Renard, "Forecasting Tropical Cyclone Motion on the Northeastern Pacific Ocean by an Analog Scheme," Monthly Weather Review. Vol. 103, August 1975.

Title: Forecasting Marine Fog Using Numerical-Model Output Parameters

Investigator: R. J. Renard, Professor of Meteorology

Sponsor: Fleet Numerical Weather Central

Objective: To evaluate the Fleet Numerical Weather Central (FNWC) Hemispheric F-TER Fog Probability Forecasts.

Summary: Fleet Numerical Weather Central (FNWC) operationally produces computerized fields of fog probability twice daily, 00 and 21 Greenwich Mean Time (GMT). The program statistically combines fog-related model output parameters to generate the probabilities, which are most prominently used by the Optimum Ship Routing group at FNWC. The product does not contain a climatological factor and it has not been extensively evaluated for accuracy, to date. The project coevaluated the F-TER probabilities in the North Pacific Ocean area for July 1974 (using over 10,000 ship reports) with climatological marine fog frequencies (used as forecast possibilities) being developed at the Naval Postgraduate School (NPS) under Naval Air Systems Command (NASC) sponsorship. Application of the Panofsky-Brier P-Score verification scheme indicated little difference in skill between the two forecast approaches. The research also developed criteria for discriminating between fog/ no fog F-Ter forecasts as a function of the probability values in the current version of the program. Work is continuing under another project (NASC sponsorship) to generally improve statistical marine-fog forecasting.

Publications: R. J. Renard, "A Coevaluation of FNWC's Fog Probability Forecasts and the NPS Marine-Fog Climatology for the North Pacific Fog Regions in Summer." Technical Report NPS51Rd75081, August 1975.

Title: Forecaster's Digest for Eastern North Pacific Ocean Tropical Cyclones

Investigator: R. J. Renard, Professor of Meteorology
W. N. Bowman, Naval Environmental Prediction Research Facility

Sponsor: Naval Environmental Prediction Research Facility

Objective: To compile climatological statistics on eastern North Pacific Tropical Cyclone behavior for presentation in a form suitable for operational Navy use.

Summary: Previous work has determined that only the operational weather satellite era (i.e., since 1965) is suitable for deriving statistics on movement and development of Eastern Tropical Pacific (EASTROPAC) cyclones. The Naval Weather Service Detachment at the National Climatic Center, Asheville, North Carolina, provided to the investigators best tracks and derived movement statistics for the ten-year period 1965-74.

Ten-year statistics and the accompanying text have been prepared on initiation and termination areas, movement statistics, durations, frequencies and forecasting of EASTROPAC cyclones by half- and whole- month periods.

Publications: R. J. Renard and W. N. Bowman, "The Climatology and Forecasting of Eastern North Pacific Ocean Tropical Cyclones,"Technical Paper No. 7-76, Naval Environmental Prediction Research Facility, Monterey, California, June 1976 (79p).

Title: Global Modeling

Investigator: R. T. Williams, Professor of Meteorology

Sponsor: Navy Environmental Prediction Research Facility

Objective: To develop and test numerical techniques for global weather prediction.

Summary: The stability properties of the Shuman pressure gradient averaging technique were investigated with the linearized shallow water equations. In the simplest case an analytic expression was obtained for the stability region, and the maximum time step was shown to be twice the value for the leapfrog scheme. When a mean flow was added to the equations, it was shown that the maximum time step must be reduced. The time averaging suggested by Robert was examined, and again a smaller time step was required. In each case however, the use of the Shuman averaging allowed a significantly longer time step than the conventional leapfrog scheme.

The possibility of using the finite element method for numerical weather prediction has been investigated by applying the method to the shallow water equations. LT Hinsman, in a M.S. thesis, applied the method to global prediction. It was found that the finite element predictions were much more accurate than corresponding finite difference forecasts, but that the finite element model required more computational effort. LT Kelley is now investigating the use of a variable element size model for tropical storm prediction. The preliminary results show that the finite element model generates noise around points where the element size changes. The forecasts also require considerable computer time.

The First GARP Global Experiment (FGGE) is a year-long global observation experiment which will begin in late 1978. A review of the experiment has been prepared and its potential usefulness to the Navy has been analyzed.

Two aspects of the monsoon circulation during the Northern Summer have been examined: the dynamics of the synoptic-scale wave disturbances generated by the instability of the zonal-mean and planetary-scale flows in the upper troposphere, and the simulation of the planetary- and synoptic-scale motions of the monsoon in a numerical model. The first part was studied with a linearized barotropic

vorticity equation, while the second used a simplified general circulation model with specified heating.

Monaco and Williams (1975) developed a global prediction model which is based on the special finite difference scheme which was designed by Dr. A. Arakawa. This model was tested by using an initial condition which gave flow directly over the pole. These initial conditions gave numerical solutions which become distorted near the pole and eventually unstable. A modified procedure near the pole was tested which gave reasonable, stable integrations. The model was also tested with topography. A high mountain (about 3 kilometers) was inserted gradually at a single grid point. This was done near the equator in an experiment and also in mid-latitudes in another. The numerical solutions were smooth even near the mountain and the integrations were stable. These results indicate that the model would be well behaved even with other surface topography.

Conference Presentations: C. P. Chang, R. T. Williams and J. B. Tupaz, "Study of Planetary and Synoptic-Scale Waves of the Northern Summer Monsoon." Presented at the GARP Study Conference on Tropical Numerical Modeling, Exeter, England, April 1976.

Publications: A. L. Schoenstadt and R. T. Williams, "The Computational Stability Properties of the Shuman Pressure Gradient Averaging Technique." Journal of Computational Physics, 21, 1976.

A. L. Schoenstadt and R. T. Williams, "The Computational Stability Properties of the Shuman Pressure Gradient Averaging Technique," Technical Report NPS-53Zh51Wu75091, September 1975.

Theses Directed: R. J. Hartinger, "Upper Level Barotropic Instability," Master's Thesis, 1975.

D. E. Hinsman, "Application of a Finite Element Method to the Barotropic Primitive Equations," Master's Thesis, 1975

DEPARTMENT OF AERONAUTICS

The research effort of the Aeronautics Department is very broadly based.

In the area of flow measurements and visualization Professors Schmidt and Miller have been investigating the aerodynamic performance of a high lift circulation controlled airfoil. Both steady and oscillating jet blowing into an oscillating free stream are being investigated.

Professor Platzer has continued his investigations into the theoretical analysis of oscillatory flows in transonic turbomachines and has obtained a complete analytical solution for slowly oscillating infinite cascades in supersonic flow. Professor Shreeve has begun making detailed measurements of the flow from a transonic rotor using pneumatic probes. He has completed further work in turbine blade row performance measurements and highly loaded rotors.

Professor Collins has continued his work in flow field visualization using holographic methods and will shortly begin velocity measurements in the transonic compressor using a laser Doppler velocimeter.

The department also has an extensive activity in damage control and aircraft fatigue measurement. Professor Lindsey is developing new instrumentation, which uses a microprocessor for data acquisition to more accurately monitor inflight fatigue damage of aircraft. Experimental work in fatigue measurements accompanies this study. Results of this research are currently being used by Naval Air Development Center, Warminster, PA, in the development of a Life Management Program for all new Navy aircraft. Professor Ball, in addition to organizing the second biennial aircraft survivability symposium, has done further analysis on aircraft fuel tank response to small arms fire and missile fragments. The object of this investigation is to develop fuel tank designs that can withstand the hydraulic ram loading. Professor Bank has continued his work on the effect on stress distributions of a hole or of a thermally degraded region.

Professor Gawain has carried out further calculations relating to the hydrodynamic stability of flow in pipes and channels. Also, working in collaboration with Professor Ball, he has devised finite difference methods of improved accuracy for the solution of linear differential equations of fourth order.

Further research activity in the Aeronautics Department have covered some important and developing fields. Professor Hess has applied modern control theoretic methods to the design of control systems and cockpit displays for V/STOL aircraft.

Professor Netzer has been active in assessing the emission levels and air quality effects from Naval Air Station aircraft operations and test cells. He has completed some further work in the area of solid fuel ramjet combustion and the burning rate characteristics of solid propellants.

Professor Layton has completed further development on basic measurements in the analysis of captured air bubble vehicles. The latter is an experimental program utilizing the department's XR-3 testcraft. Professor Biblarz has obtained an exact solution to the transonic flow equation. He has also continued his work in electrode loss mechanisms in magnetohydrodynamic generators and has done further work with high pressure discharges for electro-aerodynamic lasers.

Title: Aircraft Fuel Tank Response to Small Arms Fire and Missile Fragments (Hydraulic Ram)

Investigator: R. E. Ball, Associate Professor of Aeronautics

Sponsor: DOD Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) and Naval Weapons Center

Objectives: 1. To obtain fuel tank wall strain data and fuel pressure data caused by a ballistic penetrator; 2. To develop analytical models and computer programs that adequately describe the fuel tank response to the penetrator; and 3. To develop fuel tank designs that can withstand the hydraulic ram loading. Both metal and composite material fuel tanks are considered.

Summary: Metal aircraft fuel tanks that are subjected to ballistic impact and penetration by small arms fire and missile fragments can be severely damaged, with large petalling of the tank walls occurring at the entrance and exit points of the projectile. The damage mechanism, called hydraulic ram, is a very high pressure wave in the fuel caused by the passage of a ballistic penetrator through the fuel. An analytical and experimental hydraulic ram program has been in existence at the Naval Postgraduate School (NPS) for over three years. Fluid pressures and wall strains have been experimentally measured and analytically predicted at NPS for rectangular tanks with aluminum walls. A comprehensive summary of this work is given in Ref. 1. A method for predicting the extent of cracking in metal tank walls due to hydraulic ram is presented in Ref. 3. Very good correlation with experimental results was observed. A scanning electron microscope was used to identify the type of fracture.

Due to the fact that aircraft fuel tanks made of composite materials are now being seriously considered, the effect of hydraulic ram on composite material tank walls has been investigated. In Ref. 4, the various effects of hydraulic ram on a clamped 11 inch square, 0.067 inch thick, graphite/

epoxy wall due to penetration by a .222 caliber projectile are examined. Shots at 2600 fps caused only light damage to the plate. At 2800 fps, the hydraulic ram caused considerable damage, including total severance of the plate from its clamped support over much of the outer perimeter. The objectives of the research in Ref. 5 were to show the relative importance of the transverse shearing forces produced by hydraulic ram loading on military aircraft fuel tank joint designs for composite materials, and to propose fuel tank test section designs based upon specific composite material fuel tank design concepts for the F-16, F-18, and a Navy V/STOL delta wing. With the use of a finite element analysis, the transverse shearing force at a metal fastener was shown to be a major cause of failure at attachment, primarily by an out-of-plane push-out mode of failure. This type of failure could have a significant effect on the structural integrity of a major load carrying member of the aircraft, such as the wing box beam. In this situation, a large portion of the wing skin over the fuel tank may become detached from the spars, ribs and stringers, causing a serious degradation in the strength and stiffness of the wing. Future research will be devoted to the study of the amount of resistance to out-of-plane push-out shown by various composite attachment designs and to the determination of the amount of area over which push-out may occur.

Publications:

R. E. Ball, "Structural Response of Fluid-containing-tanks to Penetrating Projectiles (Hydraulic Ram) - A Comparison of Experimental and Analytical Results," Technical Report NPS-57Bp76051, May 1976.

R. T. Remers and R. E. Ball, "Designing Military Aircraft for Survival in Combat," Astronautics & Aeronautics, Vol. 14, No. 5, May 1976.

Theses Directed:

S. L. Fahrenkrog, "A Study of the Crack Damage in Fuel-Filled Tank Walls Due to Ballistic Penetrators," Master's Thesis, March 1976.

A. N. Duva, Jr, "Hydraulic Ram Effect on Composite Fuel Cell Entry Walls," Master's Thesis, March 1976.

H. S. Ezzard, Jr, "A Study of the Failure of Joints in Composite Material Fuel Cells Due to Hydraulic Ram Loading," Master's Thesis, June 1976.

Title: Impact of Trident on the Naval Torpedo Station Ranges

Investigators: M. H. Bank, Assistant Professor of Aeronautics, W. P. Cunningham, Professor of Physics and Chemistry, D. A. Stenz, Professor of Electrical Engineering, and C. O. Wilde, Professor of Mathematics

Sponsor: Naval Torpedo Station

Objective: Study the TRIDENT program, and delineate its impact on the NTS ranges, especially in the areas of the WSAT and FORACS test and evaluation procedures.

Summary: An important feature of this study was to obtain authentic input from officer students at NPS, and involve them in the investigations. In preparation for these activities, a seminar course (EE 4900) was conducted by D. Stentz, assisted by C. Wilde, in the final quarter of FY 75 to acquaint the students with the Navy's underwater acoustic tracking range system and explore possible thesis topics. In this connection, an NB indoctrination visit for a large group of NPS students and faculty resulted from the seminar. Two theses on NTS range studies were completed by three of the students from the seminar; one of these theses was on TRIDENT, and it is cited below as a publication resulting from this project. Another seminar course was conducted during the final quarter of FY 76 for a new group of potential thesis students, and research for two more theses is currently underway.

As part of the investigation, relevant documentation concerning the TRIDENT program was collected. Since most of the TRIDENT systems are still under development, it was often difficult to obtain information; for example, almost no data are available concerning the towed array, its beam characteristics, the need for full deployment, and its trailing (hydrodynamic) and operational characteristics. Only comparable data specifying the electrical and operational cahracteristics of the passive sonar systems, linear arrays and the STASS array could be located.

Some WSAT and FORACS test and evaluation programs that could be adapted for TRIDENT have been studied. In addition, a study of navigational characteristics of both surfaced and submerged submarines was conducted to determine whether the TRIDENT could safely perform the necessary navigational movements within the confined waters of the NTS ranges. Only limited information on the operational characteristics of a submarine towing a long thin array was found. The lack of specific information on the TRIDENT weapon towed array, fire control systems, and modes of operation make it difficult to predict the tests that will be required, and how and where they should be conducted.

Publications: M. H. Bank, W. P. Cunningham, D. A. Stentz, and C. O. Wilde, "Research Summary Report of NPS Range Design Studies," NPS-71W176081, Edited by O. B. Wilson, August 1976.

Thesis Directed: H. A. Bunch and R. G. Lacher, "On the measurement of Operational Performance of the Trident Sonar System," (U), Master's Thesis, March 1976.

Title: Aircraft Structures Research: Composite Stress Concentrations

Investigator: M. H. Bank, Assistant Professor of Aeronautics

Sponsor: Naval Air Systems Command and Foundation Research Program

Objectives: To determine the effect on the stress distribution in an advanced composite structure of a hole or thermally degraded region. Three immediate objectives are being pursued: (1) a one-parameter characterization of residual strength as a function of ballistic damage size is being attempted; (2) an investigation of the effects of low energy impact on composite plates is underway; and (3) a concurrent investigation of a liquid-crystal inspection technique for evaluation of the extent of damage supports both (1) and (2). This is a continuing program.

Summary: Improvements have been made in the composite made in the composite materials fabrication laboratory, permitting manufacture of flat plate specimens as large as 24" x 36". A precision cut-off machine with a diamond wheel has been added to facilitate specimen preparation. The ballistic-impact and ball-drop devices are operational and producing data.

A photoelastic investigation of stress concentrations around central holes in finite glass-epoxy composite plates under unaxial tension demonstrated that the state of stress was not adequately described by theoretical solutions for homogeneous orthotropic plates. Stress concentration factors were shown to be dependent on hole size. Strain gage investigations of stress concentrations around off-center holes in similar plates under uniaxial load have shown that the effect of hole size on the stress concentration factor is increased when the hole is moved toward the unloaded edge.

Ball-drop testing of graphite-epoxy panels is producing interesting results. Damage to the specimens has been detected at low energy levels, well before any visible damage takes place at the surface. Growth

of the damaged area is monitored under successive impacts until fracture occurs. An effort is being made to correlate the impact at fracture with computer predictions utilizing a finite-element method solution.

Inspection of damaged areas using various techniques has been investigated. The most promising method seems to be the use of liquid crystals to detect anomalies in the heat-transmissions properties of the material. Deliberately introduced de-bonds between laminae have been detected seven laminae from the front surface of an eight-ply plate (i.e. one lamina from the back side). Heat transfer properties of the composite material are being studied, and devices are being designed to turn this technique from a qualitative to a quantitative inspection procedure.

Publications: None

Theses Directed: Sakol Vudhivai, "Stress Concentration in Glass-Epoxy Composite Plates," Master's Thesis, December 1975.

T. J. Davis, "Ballistic Range Development," Master's Thesis,June 1976.

R. T. Schaum, "Development of a Non-Destructive Inspection Technique for Advanced Composite Materials Using Cholestric Liquid Crystals," Master's Thesis, September 1976.

Title: Electrode Loss Mechanism in Magnetohydrodynamic (MHD) Generators

Investigator: O. Biblarz, Associate Professor of Aeronautics

Sponsor: Air Force Office of Scientific Research

Objectives: To define the nature and extent of voltage drops in MHD generators attributable to the electrodes. Principal loss mechanisms studied are collision-dominated sheath losses due to the conductivity decrease of a thermal boundary layer.

Summary: The two-dimensional, active-site model of a non-emitting anode has been successfully solved in a computer using a quasi-Jacobi technique. This formulation allows the insertion of magnetic field effects and of Joule heating. The system is considered thermally stable and ionization and recombination are neglected. Future plans include the extension of our results to higher voltages and the inclusion of the ionization term in the equations.

Conference Presentation: R. C. Dolson, "A Computer Analysis of the MHD-Sheath Voltage Drop," Presented at the Institute of Electrical and Electronics Engineers International Conference on Plasma Science, University of Texas at Austin, May 1976.

Thesis Directed: R. C. Dolson, "A Computer Analysis for the Determination of Voltage Losses in Magnetohydrodynamic-Generator Plasmas," PhD Dissertation, December 1975.

Title: Applications of an Exact Non-Hodograph Solution to the Transonic Equation

Investigator: O. Biblarz, Associate Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objective: An exact solution to the transonic equation has been found which is both novel and relatively uncomplicated. The objective is to study the features of this solution which may have practical importance. Because of the generality of phase diagrams, the present approach is used to study properties of the transonic equation which are then compared with results for real airfoils.

Summary: The exact solution along with intrinsic flows which represent that solution have been established; the sonic flow result is related to other sonic solutions. It has been found that the transonic equation is essentially sonic or parabolic in character and that it is a simple matter to extend sonic solutions to the full transonic range (but with some loss of generality). A phase plot has been constructed which represents the perturbation velocities and transonic normal shocks have been investigated in the phase plane.

Conference Presentation: O. Biblarz, "Phase Plane Analysis of Transonic Flows," Presented at the American Institute of Aeronautics and Astronautics Fluid and Plasmaodynamics Conference, San Diego, California, July 1976.

Publication: O. Biblarz, "An Exact Solution to the Transonic Equation," the Israel Journal of Technology, 1975.

Title: High Pressure Discharge for Electro-Aerodynamic Lasers

Investigator: O. Biblarz, Associate Professor of Aeronautics

Sponsor: None

Objective: Fluid dynamic stabilization of discharges of interest for electric-laser applications has been shown to be very effective. This work extends previous efforts to subatmospheric discharges with screen-generated turbulence. In addition, a model for the effects of convection and turbulence on the discharge is being developed.

Summary: A test section in which air flows with speeds up to 600ft/sec was built and operated. Various configurations were tested both at atmospheric and subatmospheric pressures. The effect of reducing pressure, increasing velocity, and of introducing turbulence was to increase the power to the discharge in the order of 500 times. Future plans include a closed loop facility in which various gas combinations may be used at reduced pressures. Ultimately, a discharge geometry suitable for electric laser operation is envisaged.

Theses Directed: J. L. Barto, "Gasdynamic Effects on an Electric Discharge in Air," Master's Thesis, September 1976.

H. A. Post, "Investigation of the Velocity, Density, and Turbulence Dependance of a Discharge in Air," Master's Thesis, September 1976.

Title: Holographic & L.D.V. Studies of Low Speed Flow

Investigator: Daniel J. Collins, Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objective: Holographic interferometry and laser velocimetry will be applied to low speed flows.

Summary: Holographic investigations have been completed on a free low speed jet simulating a thrust augmentor[1]. Work has begun on L.D.V. measurement of flow fields[1]. Flow around a cylinder in slow flow has been obtained by L.D.V.[2]. Preliminary measurement using L.D.V. were begun on the fluidic jet.

Theses Directed:

I. A. Maliv, "Flow Visualization of the Turbulent Jet at the Exit of a Single Element Nozzle by Holographic Technique, and Mean Velocity Profile Measurements with a Laser Doppler Anemometer," Aeronautical Engineer Thesis, March 1976.

T. S. Wanner, "Laser Doppler Anemometer Measurement and Analytical Comparisons of Flow Around a Cylinder at Low Reynolds Number," Master's Thesis, March 1976.

Title: L.D.V. and Holographic Studies of VSTOL and Transonic Compressors

Investigator: Daniel J. Collins, Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objective: Flow measurement and visualization of flows in VSTOL propulsion, transonic flows and unsteady flows and aeroelasticity.

Summary: Further measurements have been made with the Laser Doppler Velocimeter on a thrust augmentor[1]. Work is continuing on instantaneous velocity profiles. Unsteady holographic using a television camera with a heated enclosure has been further developed[2].

Work will shortly begin on the velocity measurements in the transonic compressor. Two thesis students are presently studying the applications of the finite element method to turbomachinery calculations and transonic flow.

Theses Directed: G. P. Braun, "Time-Dependent Holographic Interferometry and Finite Element Analysis of Convective Heat Transfer within a Rectangular Enclose," Master's Thesis, September 1976.

M. K. Hollis, "Measurement of Instantaneous Velocities from a Fluidically Controlled Nozzle using a Laser Doppler Velocimeter," Master's Thesis, September 1976.

Title: Decision-Making & Optimization in the Design of Advanced Aircraft Systems

Investigator: Ulrich Haupt, Associate Professor Emeritus, Department of Aeronautics

Sponsor: Naval Air Systems Command

Objective: To evaluate recent experience gained in the design of advanced aircraft systems with respect to applying the methodology of operations research to the decision-making and optimization process in engineering.

To clarify existing problem areas;

To establish basic needs regarding feedback from industry to universities in the border regions between engineering and operations research.

Summary: The investigator visited most of the major aircraft companies in the United States, some of them twice, and discussed various aspects of this project with about one hundred engineers - most of them in responsible, design oriented positions in the aircraft industry, others in government agencies, engineering organizations, and at universities. As a result of these visits and discussions, the objectives of this project have assumed a firmer shape and they can be closely related to some fundamental developments which are taking place throughout the aircraft industry.

One of these trends can be seen in the increasing demands on design optimization as trade-offs between aerodynamic performance, weight, production cost, life-cycle cost, reliability, maintainability, and other considerations have to be evaluated. Another trend is the liberation of the designer from much drudgery as a consequence of computer-aided design. These two trends create a new and challenging situation in aircraft design. The primary responsibility of the designer has to be directed toward developing alternative proposals; coordinating, integrating, and optimizing the various elements; and finally finding the optimal design. This requires a basic

understanding of the decision making process. The corresponding implications form the subject of this project.

Publications: None

Title: Application of Manual/Automatic Control Theory to the Design of V/STOL Control/Display Systems

Investigator: R. A. Hess, Assistant Professor of Aeronautics

Sponsor: National Aeronautics and Space Administration, Ames Research Center

Objective: To apply modern control theoretic methods to the design of control systems and cockpit displays for V/STOL aircraft.

Summary: An application of an analytic pilot model to a helicopter display improvement study was undertaken. A flight director design technique was developed and implemented in a helicopter hover task. A method for analytically predicting aircraft handling qualities was introduced and finally, a general pilot-model based display design technique was developed.

Conference Presentation: R. A. Hess, "An Application of Flight Director Design Technique to a Helicopter Hover Task," Paper presented at 12th Annual Conference on Manual Control, University of Illinois, May 1976.

Publications: R. A. Hess, "A Model-Based Analysis of a Display for Helicopter Landing Approach," Institute of Electrical and Electronics Engineers Transactions on Systems, Man, and Cybernetics, July 1976. Paper also presented at 11th Annual Conference on Manual Control, Ames Research Center, California, May 1975.

R. A. Hess, "A Method for Generating Numerical Pilot Opinion Ratings Using the Optimal Pilot Model," NASA TM X-73, 101, February 1976. Paper also presented at 12th Annual Conference on Manual Control, University of Illinois, May 1976.

R. H. Hess, "Analytical Display Design for Flight Tasks Conducted Under Instrument Meterological Conditions," NASA TM X-73, 146, July 1976.

Theses Directed:

L. W. Wheat, "A Comparison of Optimal Control Theory Predictions with Actual Pilot Performance in a Helicopter Longitudinal Tracking Task," Master's Thesis, June 1975.

T. W. Duffy, "An Analysis of the Effect of a Flight Director on Pilot Performance in a Helicopter Hovering Task," Master's Thesis, March 1976.

Title: Surface Effect Ship Technology Program

Investigator: Donald M. Layton, Associate Professor of Aeronautics

Sponsor: Naval Sea Systems Command

Objective: To investigate several facets of basic and advanced Surface Effect Ship technology as they apply to Captured Air Bubble vehicles.

Summary: Two (2) tasks were developed by the Sponsor's Statement of Work and one (1) additional task was developed by the Investigator during Fiscal Year (FY) 1976. All three (3) of these tasks were completed and reported during FY 1976.

(A) Pressure Distriburion (SESPO Project). The distribution of the pressure in the plenum of the XR-3 Testcraft was determined by the use of static pressure orifices located on the wet deck of the plenum chamber. It was found that the static pressure increases from the forwarded portion of the plenum toward the rear seal, and from the sidewalls toward the center line of the plenum. The pressure profile was a direct function of the testcraft velocity, and the distribution of pressure was affected to a minor degree as the trim of the testcraft was varied. The existence of a "rooster tail" wave behind the trailing edge of the bow seal after Secondary Hump transistion was validated by an observable change in the pressure profile at the rooster tail crest.

(B) Rear Seal Air Loads (SESPO Project). The air loads on the rear seal of the XR-3 Testcraft were measured in the post-Hump velocity regieme by means of static pressure orifices attached to the face of the rear seal. The shape of the seal was determined by means of photographs of a video picture of the rear seal face against a grid painted on the inside of shape information, the air loads normal to the seal face were resolved into lift and drag loads. Evidence of a back flow at the trailing edge of the seal was observed and this reverse flow was adjudged to be due to the venting under the rear seal.

(C) Early Transition (NPS Project). Previous attempts at obtaining an early transition of Secondary Hump by mechanically lifting the bow seal just prior to Secondary Hump had not been successful. Optimum shaping of the bow seal, based on experiments conducted during FY 1975, permitted the testcraft to transition at lower values of thrust and velocity than were normally required. It was shown that with an optimally shaped bow seal, transition could be accomplished at approximately fourteen percent (14%) reduction in thrust required and a five percent (5%) reduction in velocity.

Pulications: None

Theses Directed:

R. M. Eddy, "A Survey of the Pressure Distribution withing the Plenum Chamber of the XR-3 Testcraft," Master 's Thesis,September 1975.

J. S. Payne, "Air Pressure Loads on the Rear Seal of the XR-3 Captured Air Bubble Testcraft," Master's Thesis,December 1975.

W. T. Moore, "The Effects of Rapid Raising of the Bow Seal on Early Transition of the XR-3 Captured Air Bubble Testcraft," Master's Thesis, March 1976.

Title:	Aircraft Sensors
Investigator:	Donald M. Layton, Associate Professor of Aeronautics
Sponsor:	Naval Air Systems Command
Objectives:	To study current Navy aircraft sensor configurations by aircraft types and extraploate to last two decades of the 20th Century utilizing available technology and new concepts.
Summary:	Baseline data was obtained on the sensors currently being used on fighters (F-14), and Anti-submarine (S-3) aircraft. Preliminary examination of the state of the art of aircraft sensors was commenced for use during the Fiscal Year 1977 portion of the project.
Publications:	None

Title: Aircraft Fatigue Monitoring

Investigator: Gerald H. Lindsey, Associate Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objective: To develop methods by which fatique damage of aircraft may be more accurately calculated from in-flight monitoring data.

Summary:

A microcomputer data acquisition instrument has been developed at NPS for recording in-flight strains of airplane structures by means of strain gages located near fatique critical points. The analog voltage signal from the strain gage is digitized and interrogated for maxima and minima, which are the significant points of the data for fatigue analysis purposes. These extrema are stored in solid state random access memory (RAM) in the sequence in which they occurred. At the end of each flight, the microprocessor transfers the data in RAM to magnetic tape for convenient handling and subsequent processing and use in fatigue damage calculations.

The research presently underway is directed toward obtaining a sufficient depth of understanding of material behavior to use the recorded strain data in making a reliable fatigue damage calculation. The primary effect being focused on is the influence of sequence of loading upon the damage when there is local plastic yielding at a point of stress concentration. Our experiments have shown that in the post yield state there is a significant relaxation of stress in the material, which changes dramatically the damage calculation. This reduction in stress for a given strain level reduces the damage incurred and increases the life expectancy over that calculated by ignoring the relaxation. Tests on aluminum sheets that duplicate wing panels, which are partially complete, are leading to a quantification of this effect.

Publications: None

Theses Directed:

LCDR D. M. Vidrine, "A Sequential Strain Monitor and Recorder for Use in Aircraft Fatigue Life Prediction," Master's Thesis.

LT W. C. Stanfield, "Microprogrammable Integrated Data Acquisition System--Fatigue Life Data Application," Master's Thesis.

LT C. L. Butler, "Software Design for a Fatigue Monitoring Data Acquisition System," Master's Thesis.

LT. G. M. Horne, "An Investigation of Stress Determination for Aircraft Fatigue Life Predictions from In-Flight Strain Data," Master's Thesis.

Title: Nonsteady Aerodynamic Performance of High Lift Circulation Controlled Airfoils

Investigator: J. A. Miller and L. V. Schmidt, Associate Professors of Aeronautics

Sponsor: Naval Ship Research and Development Center

Objective: To obtain aerodynamic performance data in an oscillating free stream for a typical example of high lift airfoil section whose circulation is controlled by Coanda Effect jet blowing. Both steady and oscillating jet blowing into an oscillating free stream is to be investigated.

Summary: The test section to be investigated was supplied to NPS by NSRDC and was found to be unsuitably instrumented and to have structural separations upon receipt. Subsequent to replacement of the surface pressure sampling taps and repair of the strucural defects the model was installed in the NPS Oscillating Flow Wind Tunnel and instrumented for preliminary runs in a steady free stream to confirm previous data collected by NSRDC.

Static pressure data was obtained for two angles of attack 1.67 and 5.0 degrees, at a chordwise Reynolds Number $\simeq$ 500,000 for various blowing rates corresponding to momentum coefficients, C_μ = 0.14. From this data the lift, drag and moment coefficients C_L, C_D and C_M were calculated for comparison with the earlier NSRDC data. The probable source of the substantial differences noted between the NPS data and that obtained by NSRDC was identified as leakage occasioned by the structural defects noted above. The linearity in the lift and moment data obtained at NPS gives theoretical support to the validity of these data.

Concurrent with this initial experimental phase work was undertaken to develope a valve to produce controllable oscillations in the blowing rate as well as microprocessor hardware and software for recording and processing the very large mass of oscillating pressure data. Measurement of the nonsteady pressures is effected using

a technique well established at NPS which involves measurement of system transfer functions and digital inversion permitting the recreation of actual surface pressure histories from remotely measured values. In addition to the two principal investigators, five thesis students, including one doctoral candidate, are involved in this effort.

To date a suitable valve has been developed and is currently being installed, the data acquisition system has been designed and is in the hardware procurement phase and software is being developed. It is expected that the data acquisition system will become operational by the end of 1976.

Publications: None

Thesis Directed: R. B. Johnson, "A Technique for Measuring Unsteady Pressures," Master's Thesis, September 1968.

Title: Burning Rate Characterstics of Solid Propellants

Investigator: D. W. Netzer, Associate Professor of Aeronautics

Sponsor: Naval Sea Systems Command

Objective: To develop a laser schlieren system and to apply it to the study of solid propellant combustion.

Summary: An optically active laser schlieren system was developed and used together with combustion bombs capable of operation to 3500 psi in order to study the gas phase temperature field above burning solid propellants. Advantages and limitations of the system were delineated. Ammonium perchlorate (AP) deflagration behavior at pressures below 800 psi was found to be in agreement with earlier results which used conventional color schlieren. At 1000 psi AP was found to deflagrate with a planar surface but in a pulsating manner. Surface reaction sites, if existing at all, were very small. At 2200 psi the surface was locally nonuniform but the pulsating behavior was not evident. Local reaction sites on the surface were evidenced by density gradients in the gas phase across the surface.

Publications:

J. R. Andrews and D. W. Netzer, "Laser Schlieren for Study of Solid-Propellant Deflagration," American Institute of Aeronautics and Astronautics Journal, Vol. 13, No. 4, March 1976.

J. R. Andrews and D. W. Netzer, "The development of Optically Active Laser Schlieren System with Application to High Pressure Solid Propellant Combustion," Technical Report, NPS-57Nt75082, September 1975.

Title: Solid Fuel Ramjet Combustion

Investigator: D. W. Netzer, Associate Professor of Aeronautics

Sponsor: Naval Weapons Center

Objective: To develope an internal ballistics computer model and to provide experimental data which can be used for model verification.

Summary: For the past two years experimental and theoretical studies have been conducted at the Naval Postgraduate School with the primary purpose of developing a combustion model for solid fuel ramjets. Until recently the model has had quite limited capabilities. Recently, improvements have been made in the turbulence modeling and in the techniques for obtaining numerical stability which have greatly improved the predictive capability of the model. The model predicts a fuel rich recirculation zone, a flame pattern, and a distribution of turbulence intensity which are in good agreement with experiment. In addition, fuel regression rates and patterns as a function of air flow rate are predicted which are also in reasonably good agreement with experiment. Current work with the model includes combustion efficiency predictions through the use of the unburned mass fraction of fuel and the effects of aft end mixing.

Conference Presentations:

D. W. Netzer, "Experimental Study of the Flow Field in Solid Fuel Ramjets," presented at the Joint Army, Navy, National Aeronautics Space Administration, and Air Force Workship on Airbreathing Combustors, Naval War College, Newport, RI, 12-13 August 1975.

D. W. Netzer, "Experimental Investigation of Solid Fuel Ramjet Combustors," presented at the Joint Army, Navy, National Aeronautics Space Administration, and Air Force Workshop on Solid Fuel Ramjets, Naval Postgraduate School, 8-10 June 1976.

D. W. Netzer, "Modeling Solid Fuel Ramjet Combustion," presented at the Joint Army, Navy, National Aeronautics Space Administration, and Air Force, Workshop on Solid Fuel Ramjets, Naval Postgraduate School, 8-10 June 1976.

Publications: D. W. Netzer, "Modeling Solid Fuel Ramjet Combustion," 12th Joint Army, Navy, National Aeronautics Space Administration, and Air Force Combustion Meeting, CPIA publication No. 273, Vol. II, December 1975.

Title: Emission Levels and Air Quality Effects from Naval Air Station Aircraft Operations and Test Cells

Investigator: D. W. Netzer, Associate Professor of Aeronautics

Sponsor: Naval Air Propulsion Test Center

Objective: To adopt the Air Quality Assessment Model (AQAM) to Naval air operations and to apply the model to operations at NAS Miramar. To develop a computer program which can be used to predict the effects of engine operating characteristics and test cell design on the flow in jet engine test cells.

Summary: The AQAM model developed by Argonne Laboratory for the U.S.A.F. has been modified to better simulate Naval air operations. In particular, VFR approaches, touch-and-go's, FCLP's, helicopter operations, hot refueling, and aircraft delays were added. Data were taken at NAS Miramar and used as input into the Source Inventory (total pollution per year by source type) and Short Term (1 hr. average concentrations at various receptors) models for aircraft, air base, and non-air base pollution sources. A parametric study was conducted to demonstrate the capabilities and limitations of the model.

Two computer models have been developed to predict the internal aerodynamics of jet engine test cells. One model is for studying engine exhaust gas recirculation and augmenter pressure rise. It is limited to low subsonic engine exhaust velocities. Current work is concerned with developing a model which can handle afterburning conditions. The second model is for examining the flow field in test cell exhaust stacks as a function of augmenter/stack configuration and engine flow rate.

Publications: K. I. Weal and D. W. Netzer, "Modification of an Ambient Air Quality Model for Assesment of US Naval Aviation Emmittants," Technical Report, NPS-57Nt75071, August 1975.

J. D. Hayes and D. W. Netzer, "An Investigation of the Flow in Turbojet Test Cells and Augmenters," Technical Report, NPS-57Nt75101, October 1975.

G. R. Thompson and D. W. Netzer, "An Ambient Air Quality Model for Assessment of US Naval Aviation Emittants," Technical Report, NPS-67Nt76091, September 1976.

Title: Unsteady Flows in Aircraft Propulsion Systems

Investigator: M. F. Platzer, Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objectives: The objective of this work unit is the investigation of unsteady flows in aircraft propulsion systems. The emphasis will be placed upon the development of theoretical models and experimental techniques which can contribute to our understanding of the complex unsteady flow phenomena in aircraft propulsion systems. Primary attention will be given to the analysis of unsteady flows in transonic turbomachines and to the experimental investigation of the effectiveness of unsteady flows for flow augmentation and control purposes.

Summary: The theoretical analysis of oscillatory flows in transonic turbomachines was continued during the past year. The major accomplishment was a complete analytical solution for slowly oscillating infinite cascades in supersonic flow which provides valuable insight into the convergence characteristics of numerical finite cascade solutions. Also, detailed measurements of flow characteristics and entrainment rates of oscillating jets were completed using hot-wire instrumentation.

Conference Presentations: M. F. Platzer, W. R. Chadwick, P. B. Schlien, "On the Analysis of the Aerodynamic and Flutter Characteristics of Transonic Compressor Blades,". Paper presented at the IUTAM Symposium on Aeroelasticity in Turbomachines, Paris, France, 18-23 October 1976, published in Revue Francaise de Mecanique, Numero Speciale 1976, pp. 65-72.

Publications: M. F. Platzer and R. J. Margason, "Prediction Methods for Jet V/STOL Propulsion Aerodynamics," American Institute of Aeronautics and Astronautics, Aircraft Systems and Technology Meeting, Dallas, Texas, 27-29 September 1976, AIAA - paper No. 76-932.

D. D. Liu and M. F. Platzer, "Approximate Methods for Transonic Flow Past Finite Wedge Profiles," Zeitschrift fuer angewandte Mathematik und Mechanik (ZAMM), Vol. 56, pp. 51-57, 1976.

M. F. Platzer, "Unsteady Phenomena in Turbomachines," Technical Evaluation Report, AGARD Conference Proceedings No. 177, Advisory Groups for Aerospace Research and Development, April 1976.

Theses Directed:

D. L. Weiss, "An Experimental Investigation of the Whistler Nozzle and an Analytical Investigation of a Ring Wing in Supersonic Flow," Master's Thesis, March 1976.

R. J. Veltman, "An Experimental Investigation of the Efficiency and Entrainment Rates of a Fluidically Oscillated Jet," Master's Thesis, June 1976.

R. K. Crowe, "Pulsating Combustion Device Miniaturization," Master's Thesis, December 1976.

Title: Test Data Control and Analysis

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Sponsor: Foundation Research Council (6.1)

Objective: To remotely control the acquisition of and to obtain on-line reduction of data from traversing probe systems.

Summary: A programmable data acquisition system was constructed using an inexpensive microprocessor. The system was programmed to drive a probe survey mechanism, to rotate and set a probe into the flow direction, and to scan, record and punch onto the paper tape up to 48 channels of data. A direct interface to a Hewlett-Packard Model HP 9830 calculator system will complete the system and allow immediate display of reduced data using an X-Y plotter.

Publications: None.

Thesis Directed:

D. D. Patton, "Microprogrammable Data Acquisition and Probe Control System (MIDAS IV) with Application to Compressor Testing," Master's Thesis, March 1976.

Title: Flow in Highly Loaded Rotors

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Sponsor: Foundation Research Program (6.2)

Objective: To explore the application of stationary hot wire, hot film and semi-conductor probes to the determination of the flow relative to a highly loaded rotor.

Summary: The flow in the first rotor of an impulse fan should be periodic in a stationary frame (fixed probes), or steady with respect to the rotor itself. It is proposed to determine the flow at a point in the rotor frame by controlled digital sampling (using real-time instrumentation) at one sample per revolution. Trigger signals at 1 per revolution and 1 per blade have been designed. Digital logic with phase-lock-loop circuitry enables samples to be taken at fixed peripheral locations in the rotor frame, at arbitrary speeds. A periodic flow generator was built to provide 30,000 HZ signals typical of rotor exit flow conditions. Semi-conductor measurements of impact pressure were made using the generator. Experimentation with hot wire probes will begin when the trigger and delay circuits have been incorporated satisfactorily into the real-time digital data acquisition system.

Publications: None

Title:	Turbine Blade Row Performance Measurements
Investigator:	R. P. Shreeve, Associate Professor of Aeronautics
Sponsor:	None
Objective:	To determine by test rig measurements the losses occuring in the stator and rotor blade rows of a single stage axial turbine.
Summary:	A test rig for single stage axial air turbines has been developed for subsonic and supersonic turbine stages producing less than 200 horsepower. The rig is instrumented to allow stator and rotor blade row losses (in addition to stage performance) to be calculated from measurements of forces, torques and pressures. Following successive improvements in hardware and instrumentation and the development of data reduction programs, smooth data for blade row loss coefficients has been obtained. A determination of the effects of tip clearance and axial spacing can now be made.
Publications:	None
Thesis Directed:	E. F. Robbins, "Determination of Rotor and Stator Loss Coefficients for an Axial Turbine with Supersonic Stator Exit Conditions," Master's Thesis, June 1976.

Title: Transonic Compressor Investigations

Investigator: R. P. Shreeve, Associate Professor of Aeronautics

Sponsor: Naval Air Systems Command

Objective: To investigate in detail the behavior of the flow in Transonic axial compressor stages. The ultimate goal is the accurate prediction of the performance of advanced compressors through the use of a model which better approximates the real flow behavior. The long and expensive development cycle for new engines would then be reduced.

Summary: An 11 inch diameter, 450 Horsepower single stage transonic compressor is being used in this continuing experimental program. An air turbine drives the compressor which is designed for 31000 RPM. Tests speeds have been held to 20,000 RPM while new measurement techniques were developed. The stage performace was mapped and the flow from the rotor was measured using pneumatic probes. A new combination temperature-pnematic probe was designed, built, and calibrated to determine the velocity vector in the relatively small compressor annulus. Fast response measurements of case wall static pressures were made using a single Kulite transducer with digital computer data recording. An on-line calibration technique was adopted to partially overcome the temperature sensitivity of the transducer. Programs were written to plot the measurements as pressure distributions across a blade space. The location of the leading shock wave in the rotor passage was clearly determined. Instrumentation has been installed to obtain maps of the case wall pressures using 8 transducer channels. Triggering and delay techniques will be used to analyse one blade space at a time in tests in which the machine speed will be increased toward design. Further, measurements of the flow from the rotor will be made with real-time instrumentation.

Conference Presentation: R. P. Shreeve, "Real-Time Measurements in a Transonic Compressor," Workshop on Transonic Flow Problems in Turbomachinery, Naval Postgraduate School, Monterey, CA, February 11-13, 1976.

Publication: R. P. Shreeve, D. J. Anderson, and J. A. Olson, "Calibration and Application of Multi-Sensor Pneumatic Probes for Velocity Determination with Corrections for Boundary Effects," American Institute of Aeronautics and Astronautics Paper No. 76-373, American Institute of Aeronautics and Astronautics 9th Fluid and Plasma Dynamics Conference, San Diego, California, July 14-16 1976.

Theses Directed: F. J. Dodge, "Development of a Temperature-Pneumatic Probe and Application at the Rotor Exit in a Transonic Compressor," Master's Thesis, June 1976.

G. C. Paige, "Measurement of Case Wall Pressure Signatures in a Transonic Compressor Using Real-Time Digital Instrumentation," Master's Thesis, June 1976.

DEPARTMENT OF OCEANOGRAPHY

The research program of the Department of Oceanography may be considered under four headings according to the facilities utilized and the sources of data. These headings are: (1) ship programs, (2) coastal field studies, (3) deep ocean data analyses, and (4) special studies.

SHIP PROGRAMS

There are 4 investigations in this category which make use of the Naval Postgraduate School research vessel ACANIA, a ship supported by the Oceanographer of the Navy. The first of these studies conducted by J. B. Wickham, concerns the mesoscale oceanographic characteristics of the boundary between the California Counter Current and the California Current itself. The emphasis is on seasonal variations.

The second ship study is by S. P. Tucker and involves the definition of the optical properties of the waters in a band 30 nautical miles wide and 200 miles long off the California coast between Point Reyes and Point Buchon. The objective is to understand temporal and spatial variations in the optical properties in terms of the ordinary oceanographic observables.

Also, from the ACANIA, E. C. Haderlie carries out a survey of the biology of stone and wood boring organisms in the deeper waters of the Monterey Bay. His purpose is to determine the identity and the vertical and horizontal distribution of these borers as well as their growth rates, settlement times, and destructive effects.

In chemical oceanography, the ACANIA is used by E. D. Traganza to collect samples to determine concentrations of zooplankton biomass and the correlations between the biological, chemical, and acoustical properties of the ocean.

Two other faculty members, namely, R. G. Paquette and R. H. Bourke make use of ice breakers furnished by the U.S. Coast Guard to observe and analyze ocean thermal microstructure near the ice margin in the Chukchi Sea.

COASTAL FIELD STUDIES

The first of these studies, conducted under the direction of E. B. Thornton, concerns the kinematics of breaking waves in the surf zone. It is based on measurements of water particle motion and will provide increased understanding of the energy distribution within the surf zone and associated phenomena. Measurements are being made in the surf in Hawaii.

Dr. Haderlie has been using concrete wharf pilings and other structures on the coast in identifying organisms responsible for deterioration of engineering materials placed in the sea and in determining the general biology and destructive effects of these organisms.

Another study involving coastal field work is a program in marine fog being conducted by D. F. Leipper and G. H. Jung. This project involves relationships between measurements from the R/V ACANIA and regularly obtained meteorological observations at shore stations. The project also undertakes analyses of data gathered at sea by other means such as through aircraft, satellites and commercial and weather ships. The research has been expanded to include segments in the Departments of Meteorology and also Physics and Chemistry. A coordinated survey is being conducted off Southern California in September 1976.

DEEP OCEAN DATA ANALYSIS

One program in this category is the study of oceans and mid latitude cyclones. It involves the analysis of observations before and after cyclones. The program was initiated in Oceanography but it now includes a model development and testing program by R. L. Elsberry in the Department of Meteorology. Under this program R. W. Garwood is conducting research with his mixed layer model with an eventual objective of operational forecast adaptation.

Deep ocean weather data from ocean station NOVEMBER are used by R. H. Bourke in examining the temperature and salinity fluctuations at the sea surface and in the mixed layer. He is attempting to isolate the nature of the atmospheric processes which may be responsible for creating the observed fluctuations and to determine the magnitude and effect of horizontal thermal advection on the heat content in the water column.

Ocean observations taken along latitude sections in the Atlantic Ocean during the IGY are being used by G. H. Jung as the basis for new geostrophic calculations of mass, salt and heat transported in that ocean. Values of heat carried by these large scale circulations will be compared to values transported by various smaller scale phenomena there.

SPECIAL STUDIES

J. J. von Schwind is preparing a detailed and systematic treatise covering the geophysical fluid dynamics of the ocean. This treatise will cover the fundamentals, ocean circulation theories and models, elementary and advanced wave theory, internal waves and tides, and advanced topics.

W. C. Thompson is preparing spectral wave generation graphs which will be more operationally useful than those now available. There are to be auxiliary graphs of wave steepness, wave age, and other parameters characteristic of waves undergoing generation.

Title: Subarctic Water Mass Intrusions at Ocean Weather Station NOVEMBER

Investigator: Robert H. Bourke, Assistant Professor of Oceanography

Sponsor: Fleet Numerical Weather Central

Objective: To examine the effect of horizontal thermal advection on the heat content of the upper layers of the ocean. Specifically, to correlate thermal advection anomalies with other physical properties to assess the physical reality of this term.

Summary: This is a continuation of a project to investigate the various energy fluxes controlling the heat content of the upper layers of the ocean in the vicinity of Ocean Weather Station (OWS) NOVEMBER. This station is located on the southern boundary of the transition zone separating the Subarctic Water mass from the Subtropic Water mass. A divergent heat budget equation was used to compute horizontal thermal advection changes in the upper 250 m of the ocean over the period 1962-1970. This term was correlated with salinity fluctuations over the period 1968-1970. Pulse-like periods of cool advection were associated with periods of reduced salinities suggesting these were intrusions of Subarctic Water. Over the 9 year period of analysis, these intrusions had a periodicity of 7 to 8 months with a duration of 3 to 4.5 months. It is probable these wave-like intrusions along the subtropic front are the result of the passage of nondispersive baroclinic Rossby waves.

Publications: None

Thesis Directed: John F. Pfeiffer, "Evidence of Subarctic Water Mass Intrusions at Ocean Weather Station NOVEMBER," Master's Thesis, September 1976, Published as Technical Report, NPS-68BF76091, September 1976.

Title: Biodeterioration Studies in Monterey Bay

Investigator: E. C. Haderlie, Professor of Oceanography

Sponsor: Naval Facilities Engineering Command

Objective: To identify the various organisms in the shallow water of Monterey Bay that are responsible for the deterioration of engineering materials placed in the sea, and to determine the general biology and destructive effects of these organisms.

Summary: This is a long-term project that has been underway for several years. During the past year emphasis has been on the biodeterioration of concrete wharf pilings and the evaluation of tropical woods to wood borer attack. Certain types of concrete have been found to be totally resistant to marine borers, while other types are subject to severe deterioration in the Monterey Harbor. Several types of tropical woods have been found to resist wood borers, but other types previously reported to be immune to attack are bored both by shipworms and gribbles.

Publications: E. C. Haderlie, "Fouling Communities in the Intertidal Zone on Wooden and Concrete Pilings at Monterey, California". Corrosion and Fouling, Juan-les-Pins, France, 1976.

Title: Biology of Stone and Wood Boring Organisms in Monterey Bay and the Monterey Submarine Canyon

Investigator: E. C. Haderlie, Professor of Oceanography

Sponsor: Office of Naval Research

Objectives: To determine the identity, vertical and horizontal distribution, and the substrate preference of major stone and wood borers in the deeper waters of Monterey Bay, and to effect of these organisms by exposing experimental materials at various depths to be recovered at regular intervals for analysis.

Summary: This is a long-term study that will require several years to complete. During the past year extensive dredging operations have continued, with special emphasis on recovery of sedimentary rock from the walls of the Monterey Canyon and on the floor of the Bay. Experimental materials have been recovered and analyzed, and new arrays have been exposed. Numerous species of stone borers have been found in the recovered rock and their vertical and horizontal distribution is being mapped. Techniques for measuring directly the growth rates of stone borers have been developed, and in some cases these rates exceed by several orders of magnitude any recorded before.

Publications: E. C. Haderlie, "Destructive Marine Wood and Stone Borers in Monterey Bay," In: J. M. Sharpley and A. M. Kaplan (Eds.) Proceedings of the Third International Biodegradation Symposium Applied Science Publication, London, England, 1976.

Title: Mass, Salt and Heat Transports in the Atlantic Ocean During the IGY

Investigator: Glenn H. Jung, Professor of Oceanography

Sponsor: Foundation Research Program (6.1)

Objective: (1) Use computer program to calculate geostrophic currents and associated transport values through vertical crosssections across the Atlantic Ocean at 36, 32, 24, 16 and 8N latitude; eventually sections at 48N and at 8, 16, 24, and 32S will also be processed;
(2) Develop computer plot and analysis program for results display;
(3) Compare data when separated seasonally to describe seasonal variation.

Summary: Card decks punched for use on an earlier NPS computer were adapted to present computer program format; cards for observations between depths of 3000 meters and the ocean floor were punched and added, as well as title cards with basic information for each of the 267 stations (comprising 5942 observations of temperature and salinity versus depth). Sections were processed with at least three runs each to obtain adjustment of the level of no motion (LNM) so net mass and salt transport values across each section are approximately zero. The initial run LNM was a first guess; the second run attempted to overcompensate the net results of the first trial; and the final run LNM was based on careful comparisons between the first and second trials by which selection of the optimum LNM was made.

The total observations for sections at 36, 32, 24, 16, and 8N have been processed in this manner. Also the earlier 40N results summarized by Greeson have been recalculated for use here. The net resulting heat transport values at 40 and 36N compare well with prior estimates interpolated from earlier data for nearby sections. From 32 through 16N the new calculations are significantly lower than prior estimates; this may be the result of

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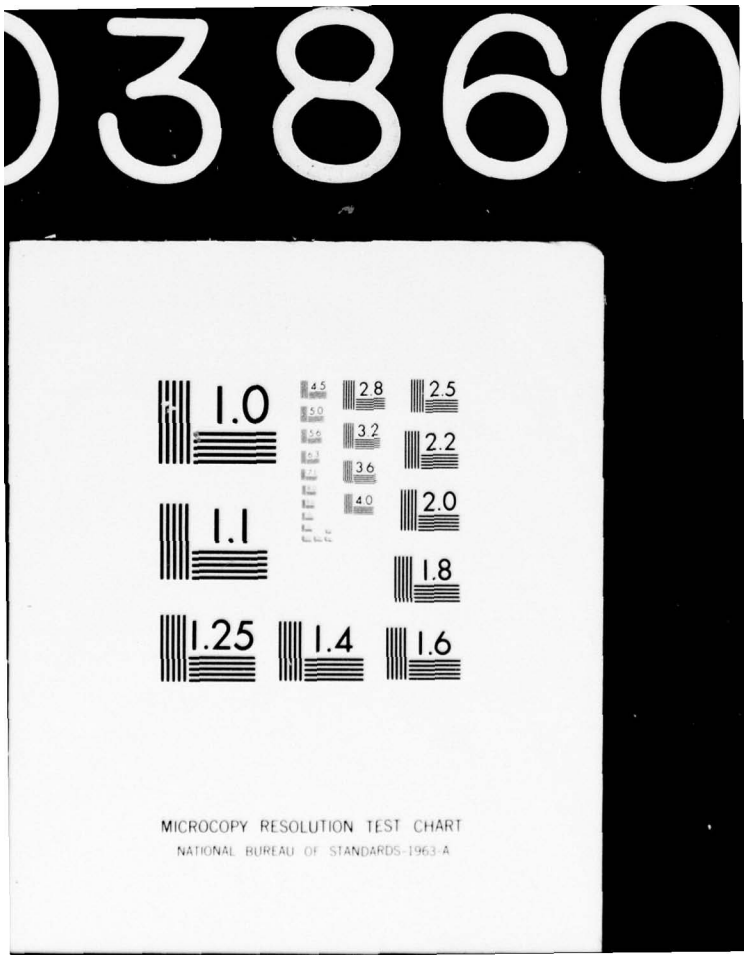
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IGY sections combining sets of observations taken during different years and seasons for one latitude (as for 32N and 24-27N); at 16N the heat transport value is very small and poleward, taken during the same autumn season as the bulk of the 24N observations; this may be reflecting an actual anomalously low heat transport during that particular season and year. At 8N the net transport is equatorward which has been checked as computationally correct, but this change in direction remains to be explained. Data at 8N are taken about 6 months prior to observations at 24 and 16N and may be consistent with those low values mentioned above. The level of no motion used varies somewhat around the 1100-meter level in the open ocean; it is clear through the balancing process used for optimizing the LNM that no significant departure from this general value will permit the required balance of mass and salt transport across each section.

A thesis student has begun work on summarizing the mass transport calculations into an overall three-dimensional circulation model of the North Atlantic Ocean between 40 and 8N. Careful comparison of these with earlier calculations will be included, and comparison with available actual mass transport and current observations.

Code 481 of ONR has approved a proposal for continuation of this project during the next academic year, when detailed summaries of the salt and heat energy circulations of the North Atlantic should be completed from 0 to 48N. Comparisons of these large-scale transports with those effected by smaller-scale eddies will be made; objectives (2) and (3) will be done. Future proposed studies beyond next year will continue this work into the South Atlantic Ocean.

Publications: None

Title: Oceanographic Investigation Associated with the Marginal Sea-Ice Zone of the Chukchi Sea

Investigators: R. G. Paquette and R. H. Bourke, Professors of Oceanography

Sponsor: Arctic Submarine Laboratory, Naval Undersea Center

Objective: To continue with field experiments and data analysis to discover the mechanisms responsible for the formation of mesoscale temperature fluctuations found in the vicinity of the ice edge in the Chukchi Sea. This project is a continuation of studies made in Fiscal Years 1972 to 1975 under general title MIZPAC.

Summary: Experimental measurements were made from a Coast Guard icebreaker in August 1975 using a conductivity-temperature-depth recorder (CTD) and a hand-lowered, direct-reading current meter. Measurements began in the warm, ice-free waters off Nome and generally followed the previous year's track to the ice margin. Unlike previous cruises, mesostructure was mostly found in ice-free waters immediately south of the ice edge. Current meter measurements indicated this to be a region of complex flow. No correlation existed between direction of flow and ice margin orientation. Spatial correlation of mesostructure elements was poor most likely because the observational measurements across the ice margin or across a region of mesostructure were not aligned with the direction of flow. An unusual finding was the occurrence of an anomalously warm bottom water overlying much of the Chukchi Shelf. This water, often more than 1^0C warmer than the relict bottom water normally found in the Chukchi Sea in summer, is probably Atlantic water from the Arctic Ocean which has impusively surged up the canyons near the shelf edge and spilled over onto the shelf.

Conference Presentation: R. H. Bourke and R. G. Paquette, "Ocean Dynamics Leading to Temperature Mesostructure Near the Arctic Ice Margin," paper presented at the Fall Annual Meeting, American Geophysical Union, San Francisco, December 1975. Abstract in: Transactions, American Geophysical Union, Vol. 56 (12), 1975.

Publications: R. H. Bourke and R. G. Paquette, "Atlantic Water on the Chukchi Shelf," Geophysical Research Letters, 3 (10), 629-632, 1976. Also published as Technical Report NPS-68BF76121, December 1976.

Thesis Directed: W. J. Zuberbuhler and J. A. Roeder, "Oceanography, Mesostructure, and Currents in the Pacific Marginal Sea-Ice Zone - - MISPAC 75," Master's Thesis, September 1976. Also published as Technical Report, NPS-68PA76091, September 1976.

Title: Environmental Factors Affecting Sea-to-Beach Solid Cargo Transfer

Investigator: W. C. Thompson, Professor of Oceanography

Sponsor: Naval Coastal Systems Laboratory

Objectives: To evaluate the influence of a large number of environmental parameters on the logistics operation of solid cargo transfer from supply ships offshore to the beach or to shore facilities following the assault phase of an amphibious operation.

Summary: Analysis procedures developed at the Naval Coastal Systems Laboratory (NCSL) (ref: "Guide to the Analysis of Environmental Requirements for Naval Coastal Operations"; Dorman, Sterwart and Tolbert; NCSL, Feb. 1975) were used to assess the influence of 70 environmental parameters on the logistics of transferring solid cargo ashore from supply ships under secure beach conditions following an amphibious assault. The operational scenarios analysed include: cargo off-loading of ship to landing craft, landing craft transit to the beach, transit across the beach, supply ship transit to a shore facility, and cargo off-loading at the shore facility. The effect of each parameter on each scenario was quantitatively evaluated and critical points and go/no go situations identified. A large abstracted bibliography on the logistics of marine cargo transfer is included. This analysis constitutes an element of the Naval Inshore Warfare Program of NCSL designed to determine the status of environmental information collection and use in naval coastal operations.

Publications: None

Thesis Directed: A. W. Winter, "Analysis of Environmental Factors Affecting Sea/Beach Solid Cargo Transfer," Master's Thesis, Technical Report, NPS-68WiTh76091, September 1976.

Title: Ocean Wave Climatology for the California Coast

Investigator: W. C. Thompson, Professor of Oceanography

Sponsor: Department of Navigation and Ocean Development, State of California

Objectives: a. To prepare specifications for the production of ocean wave statistics for the coast of California from non-spectral wave analyses contained in the archives of the Fleet Numerical Weather Central (FNWC), Monterey, California.

b. To develop formats for presenting wave statistics compiled from FNWC spectral ocean wave analyses.

Summary: The state of California plans to produce improved ocean wave statistics for the California coast for coastal engineering use. The technical specifications for producing these statistics from non-spectral (singular) wave hindcasts archived in FNWC were developed under this contract (Objective (a)). Meteorology International, Inc. is currently producing statistics under a contract with the state in accordance with these specifications. Looking to the future, the possibility of compiling ocean wave statistics from FNWC spectral wave hindcasts was examined (Objective (b)). It was determined that climatological wave data that can be shoaled and refracted from a deep-water station can be compiled in two forms from spectral hindcasts: (1) significant wave statistics, which are similar to tables in current use except that the simultaneous occurrence of multiple wave trains is accounted for, and (2) spectral element statistics, which give the occurrence of energy densities contained in a matrix of 15 frequency bands and 12 directions bands. The uses for spectral statistics are not now developed but appear to be in the realm of resonant reaction of structures to waves.

Conference Presentation:	W. C. Thompson and F. M. Reynolds. "Ocean Wave Statistics from FNWC Spectral Analyses," Presented at the 15th International Conference on Coastal Engineering, Honolulu, Hawaii, 11-17 July 1976.
Publications:	W. C. Thompson, "Specifications for the Production of Ocean Wave Statistics for the California Coast from FNWC Singular Wave Analyses," Technical Report, NPS-68Th76031, March 1976.
Thesis Directed:	F. M. Reynolds, "Climatological Wave Statistics Derived from FNWC Synoptic Spectral Wave Analyses," Master's Thesis and published as a Technical Report, NPS-58ReTh76061, June 1976.

Title: Small Scale Interactions and Energy Exchange in the Upper Ocean

Investigator: E. B. Thornton and N. E. J. Boston, Associate Professors of Oceanography
K. L. Davidson, Associate Professor of Meterology
T. M. Houlihan, Associate Professor of Mechanical Engineering

Sponsor: Office of Naval Research

Objective: To determine the relationship of fluctuating quantities of waves, temperature, turbulent velocities, and conductivity to each other, and to determine their effect of acoustic transmission over short ($\sim$2m) distance.

Summary: A stochastic model of surface wave-induced temperature fluctuations was derived by obtaining an exact solution to the diffusion equation assuming the temperature isotherms are horizontal and the mean temperature gradient constant; linear wave theory is used to describe the wave spectral components. The model illustrates that moderate narrow banded swell type waves do little mixing and serve only to pump the thermocline (and temperature field) up and down. Using this model, a means for separating turbulent and surface wave-induced temperature fluctuations is demonstrated. Spectral measurements of temperature and waves made from the Naval Undersea Research and Development Center's Oceanographic Research Platform off Mission Beach, California are used to apply the methods developed. Spectra of temperature fluctuations and waves were computed for a number of cases over a 3-year sequence of experiments. The experimental results show reasonable correlation with theory in the upper ten meters of the ocean. Reduced coherence between waves and temperature is shown to be due to ambient turbulence and nonlinear modulation of the surface wave-induced temperature fluctuations by internal waves. The turbulent temperature spectra are interpreted as reflecting the behavior of the velocity field. Power law slopes were found indicating buoyant (-3) and inertial subranges (-2 and -5/3).

The equilibrium region in the frequency spectrum of wind generated waves was rederived. Laboratory and theoretical work show that wave breaking is the result of kinematic instability, suggesting that wave celerity is the governing parameter in the equilibrium region. Using similarity arguments, a genral formulation is rederived giving the wave spectrum, $S_\eta(\omega) \propto \omega^{-3}$. Wave and velocity measurements made in deep and shallow water are presented showing agreement with theory.

Publications:

E. B. Thornton and N. E. J. Boston, "Small Scale Interactions and Energy Changes in the Upper Ocean," Technical Report, NPS 68Tm76061, May 1976.

E. B. Thornton, "Redirivation of the Equilibrium Spectrum of Wind Generated Waves," Journal of Physical Oceanography, January 1977.

Title: Kinematics of Breaking Waves in the Surf Zone

Investigator: E. B. Thornton, Associate Professor of Oceanography

Sponsor: Office of Naval Research

Objective: Basic studies are being made on the kinematics of water-particle motion within the surf zone and of breaking waves. These measurements will provide an increased understanding of the energy distribution within the surf zone, water-sediment interactions, breakdown of wave-induced motion to turbulence, and non-linearities involved in describing breaking waves.

Summary: Measurement of waves, and vertical and horizontal water particle velocities were made of spilling, plunging and surging breakers at sandy beaches in the vicinity of Monterey, California. The measured breaking waves, derived characteristically from swelltype waves, can be described as highly nonlinear. Spectra and cross spectra were calculated between waves and velocities. Secondary waves were noted visually and by the strong harmonics in the spectra. The strength of the harmonics is related to the beach steepness, wave height and period. The phase difference between waves and horizontal velocities indicates the unstable crest of the wave leads the velocities on the average by 5-20 degrees. Phase measurements between wave gauges in a line perpendicular to the shore show breaking waves to be frequency nondispersive indicating phase-coupling of the various wave components. The coherence squared values between the sea surface elevation and the horizontal water particle velocity were high in all runs, ranging above 0.8 at the peak of the spectra. The high coherence suggests that most of the motion in the body of breaking waves is wave-induced and not turbulent.

Publications: E. B. Thornton, J. J. Galvin, F. L. Bub, D. P. Richardson, "Kinematics of Breaking Waves," Proceedings 13th Int. Coastal Engineering Conf., ASCE, July 1976.

Theses Directed:

J. J. Galvin, "Kinematics of Surf Zone Breaking Waves; Measurement and Analysis," Master's Thesis, September 1975.

R. M. Smith, "Breaking Wave Criterion on a Sloping Beach," Master's Thesis, September 1976.

Title: Investigation of Biochemical Relationships for Determining Concentrations of Zooplankton Biomass and its Correlation with Chemical and Acoustical Properties of the Ocean.

Investigator: E. D. Traganza, Associate Professor of Oceanography

Sponsor: Office of Naval Research

Objective: To study biochemical relationships associated with biomass and trophic level in marine zooplankton.

Summary: Sonar systems are limited by the reverberation of marine organisms. One hypothesis is that zooplankton estimates can be useful in predicting this "volume reverberation" by virtue of their importance in marine food chains. In the past there have been no simple, reliable methods which would give estimates of zooplankton biomass. Now there is considerable promise that biochemical relationships of cellular constituents can be used to measure the concentration of zooplankton and identify their trophic level. We have completed our evaluation of carbon as a measure of total biomass and adenosine triphosphate (ATP) as a measure of living biomass in marine zooplankton. The method we developed for carbon has proven to be highly successful and has received a wide international response from other investigators. The central problem with the ATP method is the conversion factor, C/ATP, which relates ATP content to biomass. The C/ATP ratio was relatively uniform in a pure species, but in ocean samples of mixed composition it showed the scatter one might expect of a semi-random mixture of species having C/ATP ratios varying manyfold to either side of the mean. The ATP method, therefore, probably will require calibration for a given area and possibly season before it can be used as a measure of living zooplankton biomass. A computer simulation model of seasonal variations of the Monterey ecosystem has indicated the possibility of a close correspondence between the number of major seasonal plankton variations and major wind driven upwelling variations. Evaluation of this suggestion must be weighed against suspected effects of the seasonal ebb and flow of the California undercurrent which is also coupled to major atmospheric variation. An important effort for the study of biomass distribution is the ongoing development of a size

sampling, in situ, net system (SSISNTE). An initial wind tunnel study has been completed in cooperation with the department of Mechanical Engineering. Other new developments include the acquisition of a high pressure liquid chromatograph system for the analysis of other cellular constituents. The first application will be directed toward the amino acid taurine, which, as a constituent found primarily in animals, may be useful as a means to discriminate phytoplankton biomass from zooplankton biomass in samples of mixed composition.

Publications:

E. D. Traganza, J. C. Radney and K. J. Graham, "A Convient Method for the Determination of Carbon in Marine Net Zooplankton," Marine Chemistry, 4, 1976.

E. D. Traganza and K. J. Graham, "Carbon/Adenosine Triphosphate Ratios in Marine Zooplankton," American Chemical Society, 31st North Western Regional Meeting, University of Nevada at Reno, 14-15 June 1976. (Abstract). Also in EOS Transactions, American Geophysical Union, 57(12), December 1976.

E. D. Traganza, K. J. Graham, R. T. Pearson, J. C. Radney, and J. S. Anderson, "Carbon/Adenosine Triphosphate Ratios in Marine Zooplankton and the Annual Oceanography off Monterey, California, 1974," Technical Report NPS-58Tg76041, April 1976.

Theses Directed:

D. Hendrickson, "An Evaluation of a Computer Simulation Model of Plankton Dynamics in Monterey Bay," Master's Thesis, September 1976.

R. Mitchke, "Design and Wind Tunnel Test of a Size Sampling, in situ, Net System (SSISNET)," Master's Thesis, September 1976.

Title: Size and Number Distributions of Suspended Particulates in the 1.5 to 35 Micron Range in Central California Coastal Waters in Relation to the Spacial and Temporal Variations of Water Temperature and Density

Investigator: Stevens P. Tucker, Assistant Professor of Oceanography

Sponsor: Foundation Research Program (6.1)

Summary: The geographical and seasonal distribution with depth of 1 - 35 micron particles suspended in sea water is investigated by means of standard hydrographic techniques. The size analyses are made with a 15-channel Coulter counter and include data from four cruises to the north and south of Monterey Bay, California. The size distributions are presented as isometric drawings showing particle number density vs. particle size as functions of depth from the surface in the case of single station data and of horizontal distance when data are for a given depth along lines of stations located at distances of 1, 2, 3, 5, 7, 10, 15, 20, 25, and 30 n mi from shore, or in the case of Monterey Bay, separated by a distance of 1.5 n mi. A paper for submission to the Journal of the American Geophysical Union and a longer technical report containing all the oceanographic observations from the four cruises will be completed by early January 1977.

Publications: None.

Title: Dynamics of the Oceans

Investigator: J. J. Von Schwind, Associate Professor of Oceanography

Sponsor: Naval Sea Systems Command

Objective: To prepare a detailed and systematic treatise covering the geophysical fluid dynamics of the oceans. When complete, the said treatise will include fundamental and advanced topics and be so structured and written as to be particularly useful to technical persons whose work involves the ocean environment but who may have little or no formal education in theorectical phisical oceanography.

Summary: The treatise in its entirety will consist of four major parts: (1) Fundamentals of Geophysical Fluid Dynamics; (2) Ocean circulation Theories and Models; (3) Elementary and Advanced Wave Theories, Internal Waves, Tides; and (4) Advanced Topics in the Fluid Dynamics of the Ocean. At the present time, the subject matter to be covered is found only in a wide variety of sources, ranging from textbooks and technical journals to personal unpublished notes. To date most of the first section "Fundamentals of Geophysical Fluid Dynamics" has been completed.

Publications: None

Title: Structure of the California Countercurrent

Investigator: J. B. Wickham, Associate Professor of Oceanography

Sponsor: Foundation Research Program (6.1)

Objective: To describe the structure and flow in the latitude of Monterey in the California Countercurrent, including the delineation of mesoscale oceanographic features of the system in the vicinity of its boundary with the California Current.

Summary: The most interesting result, from preliminary analysis of new XBT data acquired from the National Marine Fisheries Service (NMFS), is that a cyclonic eddy delineated by direct current measurements in early August 1972 appears to have persisted to nearly the end of that month. Observations of intermediate times suggest variations in the eddy's form and weakening during that period. Information on such short time scales of features such as this are rare.

Additional analysis has been completed on the annual variation of the water masses in the countercurrent region. It indicates that the "southern water" characteristics, at least in the year 1972-1973, appear with greatest intensity in a narrow band within 20 km of the coast in the period August through December with an abrupt onset and cessation. The August arrival is consistent with the pattern observed in 1971-72 in the same region.

A filamental structure of this same type with a maximum near the shelf edge also appears in the geostrophic analysis of "southern water" flow in the Coronado trough (off San Diego), the data for this analysis having been collected by this reporter in August 1971. Current meter measurements off of Oregon and Washington also indicate a "shelf-edge" jet.

Data processing continues, particularly digitizing of STD analogue records obtained by NMFS. Their analysis is needed to confirm, by geostrophy, the preliminary conclusions about the persistence of the cyclonic eddy described above.

Thesis Directed:

C. S. Nelson, "Wind Stress and Wind Stress Curl Over the California Current," Master's Thesis, 1976.

DEPARTMENT OF MECHANICAL ENGINEERING RESEARCH PROGRAM FY76

The Department of Mechanical Engineering has a diversity of research interest and talent as is evidenced by the variety of projects. The various categories are as follows: (1) materials science, (2) mechanical and component design, (3) heat transfer, (4) structures, vibrations, and solids, (5) guns and missiles, (6) hydrodynamics and fluid mechanics, (7) environment and energy, (8) laser technology, and (9) shipboard automation.

MATERIALS SCIENCE

The Naval Postgraduate School has a strong commitment in Materials Science, with excellent laboratory facilities and active faculty. Professor Jeff Perkins directs projects in several areas, including (1) materials development for ship silencing applications, (2) failure analysis and performance optimization of lead-acid and silver-zinc submarine batteries, (3) corrosion of sacrificial anode materials used for cathodic protection of ships hulls, (4) velocity effects on corrosion of structural materials in seawater, (5) corrosion of explosively-bonded transition joints between aluminum (ships superstructure) and steel (deck) under salt-spray conditions. Other active projects involve development of subgrain-strengthened alloys through thermomechanical treatment, and ballistic materials testing. These projects are supported by extensive microscopic, microanalytical, electrochemical, and mechanical behavior research facilities.

MECHANICAL AND COMPONENT DESIGN

The Mechanical Engineering Department is developing a research activity in the area of advanced marine vehicle synthesis and design. To determine the current state-of-the-art, a series of lectures were organized. Speakers included engineers from NAVSEA, NAVSEC and industry. Based on the information accumulated during the year, future directions for M.E. activity is being evaluated.

A computer program for synthesis of destroyer-type ships has been obtained from Center for Naval Analysis. The program is being adapted to use with the NPS IBM 360 computer. An evaluation of the vulnerability of the hull of a remotely controlled minesweeper is underway. The work is being accomplished for Minesweeper Squadron 12.

Professors A. J. Perkins and T. McNelley, together with several thesis students, have investigated material problems related to design. The areas of activity include, corrosion of the interface between aluminum superstructure and steel decks, velocity effects of corrosion on structural materials in sea water, high damping capacity materials for ship silencing applications, and failure analysis of

lead acid submarine batteries.

Professor J. Brock investigated the problem of asymmetric loading of annular elastic shells. The work, containing formulas and results for four cases, has been published in the Journal of Applied Mechanics, Vol. 43, Series E, No. 2, June 1976, pp. 353-355. Two of these cases correct formulas and results for cases in the literature. The formulas and results for the remaining two cases are presented for the first time.

Under the supervision of Professor P. Marto, LT H. Search has considered the feasibility of compact main condensers aboard surface ships and submarines. The investigation examines possible weight, volume and life cycle cost payoffs, and the impact upon overall ship design and machinery layout.

HEAT TRANSFER

Heat Transfer is an extremely important facet of the Mechanical Engineering Department. Transfer of heat is a pervasive phenomenon which occurs to some degree in all engineering systems. Over the past year the Department has continued to pursue a vigorous program of heat transfer research.

In a joint Departments of Mechanical Engineering and Aeronautics project Professors Pucci and Miller have studied the Fouling of Marine Gas Turbine Waste-Heat Systems. The purpose of this program was to assist NAVSEC and NSRDC-Annapolis in the survey of the state-of-the-art in the definition of those parameters affecting the fouling of marine gas turbine waste-heat recovery systems.

Professor Kelleher has been continuing the investigation of the effects of gravity on the performance of gas loaded heat pipes. A third experimental heat pipe has been constructed and is currently undergoing tests employing liquid crystals to map the surface temperature on the heat pipe condenser. Professor Kelleher is also investigating the effects of secondary motion due to centrifugal forces on the heat transfer in curved ducts. The results would be very useful in analyzing the heat transfer on turbine blades or other flow fields with curved streamlines.

Professor Cooper has been investigating the heat transfer and pressure distribution on cylinders placed in close proximity to a wall when subjected to a flow normal to the cylinder axis. Using liquid crystal thermography Professor Cooper has determined the effect of the cylinder to wall distance on the drag coefficient and the heat transfer coefficient for the cylinder.

Professor Brock has been investigating the transient temperature distribution in an insulated metal pipe containing a fluid having a given thermal history. A method of solution has been developed for the thermal history in the wall of the pipe which is externally

insulated and through which a fluid is flowing with given temperature, pressure and flow rate as functions of time. The appropriate nonlinear partial differential equation accounting for variable thermal properties has been solved on a digital computer using a Crank-Nicolson scheme to assure stability. The results are useful in analyzing piping and pressure vessels which may experience severe thermal stress transients due to the rapid variation in the temperature - pressure - flow conditions of their fluid contents.

Professor Marto has continued to investigate the heat transfer performance of rotating, wickless heat pipes. A new experimental heat pipe has been constructed and tests are underway to study ways to augment performance. Professor Marto has used liquid crystals to map the surface temperature of a heating foil during nucleate boiling of thin liquid films of water, alcohol and freon. Professor Marto has recently begun a heat transfer analysis of main steam condensers aboard surface ships and submarines. A feasibility study is underway to examine compact condenser designs and the possible payoffs in weight, volume and life-cycle costs.

STRUCTURES, VIBRATIONS, AND SOLIDS

Professors G. Cantin, D. Salinas, and R. E. Newton have continued work on applications of the finite element method. Professor Cantin has studied both elastic and inelastic responses of explosively loaded structures, comparing the efficacy of four widely used standard programs: SAP IV, NONSAP, MARC CDC and NASTRAN. During the spring quarter, while serving as visiting professor at the Université de Technologie in Compiègne, France, he participated in the development of a new algorithm for constructing continuous stress fields from the displacement fields found by finite element method (FEM). A previously initiated study on methods for the experimental determination of elastic constant of anisotropic materials was continued.

Professor Salinas has completed extensive revisions to his previously developed elastic-plastic FEM program. The new version features a compact storage scheme for coefficient matrices with a resulting substantial reduction in storage requirements.

Professor Newton has completed a study on the response of submarine hull structures to nuclear blast waves. The technique developed allows resolution of the three-dimensional problem into an equivalent set of two-dimensional problems. For a representative structure FEM is used to determine critical combinations of blast and submergence pressures sufficient to produce shell collapse.

Professor J. E. Brock has investigated methods for estimating the gravest frequency of a vibrating system. Two major extensions of the method of Dunkerley have resulted. First of these is a technique for suppressing rigid body modes whose presence makes the classical form of the method inapplicable. The second is an iterative process which yields major accuracy gains for successive estimates. He has shown the applicability of these developments to a wide variety of discrete and continuous systems.

GUNS AND MISSILES

Several professors are involved in a gun-related research; these are Professors Nunn*, Houlihan, Perkins, Edwards, Salinas and Fuhs. Results from Professor Nunn's work on liquid gun propellants was published in ASME Journal of Engineering for Industry. The dynamics of liquid gun propellant injection continues as an active research area under the leadership of Professor Houlihan; the work is funded by Naval Ordnance Station, Indian Head, MD. Liquid gun propellants offer many advantages especially in logistics. Digital simulation of propellant injection process has been completed. External burning in the supersonic stream near the base of a projectile can eliminate base drag and even provide a net thrust on the base to partially overcome nose drag. Professor Fuhs has investigated external burning with the goal of introducing performance parameters into a trajectory computer code.

Professor Salinas has investigated the elastic-plastic behavior of an obturator using a finite element method with an optimal compact storage scheme. The scheme provides a substantial improvement in computer efficiency over existing methods.

HYDRODYNAMICS AND FLUID MECHANICS

Hydrodynamics and fluid mechanics are a vital technology for the Navy; the Mechanical Engineering Department has a strong research program in support of Navy needs.

Professor T. Sarpkaya has investigated the problem of cable strumming, periodic flow about bluff bodies, effects of polymers on the lift and drag characteristics of hydrofoils, the vortex breakdown phenomenon in connection with the flight of delta wing aircraft, and the stability of swirling flows. During the past year, Professor Sarpkaya designed and constructed a large U-shaped water tunnel facility and carried out extensive tests on smooth and rough cylinders to predict wave forces on ocean structures. This work attracted world-wide attention and several letters of commendation from the Navy sponsors. Professor Sarpkaya is currently building a new vertical water tunnel to simulate impulsive flow about cylinders and flow about slender bodies at high angles of incidence.

Professor Garrison has continued his research in numerical free-surface hydrodynamics, his most recent effort being devoted to the second-order theory of wave-body interactions. He has also carried out fundamental experimental research on the oscillatory flow past circular cylinders at critical Reynolds number.

Research has been initiated in FY76 by Professor Pucci on the subject of the Optimized Ship Exhaust Eductor. The purpose of this investigation is to assist NSRDC-Annapolis in the design of exhaust gas stack eductors for shipboard gas turbine propulsion plants. The program involves the design, construction and testing of scale models.

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*On leave at ONR Office, London

During the FY76 a major portion of the design of the experimental facility was completed, and some of the equipment fabricated.

ENVIRONMENT AND ENERGY

During FY76 several faculty members have contributed to the area of environmental problems and new energy sources. Professor Houlihan has improved upon prototype operation of an automatic oil monitoring system which utilizes a direct difference method of total organic carbon determination. His efforts have concentrated on achieving rapid evaluation of samples injected into the system. Professor Kelleher has been investigating the optimization of the design of Ocean Thermal Energy Conversion (OTEC) power generating plants. These are power plants in which the naturally occurring temperature differences in the oceans are utilized to generate electric power. The study has attempted to formulate an engineering design which takes into account the cost of the various system components and then to optimize the design based on a minimum cost of the entire system. Professor Nguyen continues his research activities in the field of nuclear reactor dynamics with temperature dependent feedback. Solutions for the two following problems have been obtained and published: the one-velocity space-dependent dynamics behavior following asymmetric disturbances, and the multi-group space-dependent transient for uniform initial conditions.

LASER TECHNOLOGY

The DoD annual budget in high energy lasers is approaching $200,000,000. High energy lasers will have a significant impact on future military operations; the influence of HEL on military operations will be as great as the advent of nuclear detonations. The Mechanical Engineering Department has as active research program oriented to the many new and challenging laser problems.

Professor Houlihan is a member of the research team measuring propagation of laser beams in the marine atmosphere. His knowledge concerning instrumentation and turbulence contributes to the overall goals of the propagation research.

On 6-8 April 1976, NPS hosted a workshop on nuclear pumped lasers. The workshop was sponsored by ONR and AFOSR and was attended by about 40 engineers and scientists from the major laser laboratories in the U.S.A. The aim of the workshop, which was organized by Professors Nguyen and Fuhs, was to identify research essential to development of nuclear pumped lasers.

LCDR Fenton Carey working under the guidance of Professor Fuhs completed his Ph.D. dissertation on transonic thermal blooming. As a result of the research the boundaries where serious transonic thermal blooming occurs have been delineated. Compressible flow over a laser turret causes phase distortion in the laser beam. Optimum turret designs are being investigated by Professor Fuhs and Adjunct Research Professor Vanderplaats.

SHIPBOARD AUTOMATION

The Navy is placing increased emphasis on shipboard automation. Among the reasons for this emphasis is the ability to operate an automated ship with fewer men and the ability to increase fuel economy. In the rework of Building 500, space was set aside for a shipboard automation laboratory. Professor Houlihan is initiating research oriented toward automated propulsion control.

Title: Transient Temperature Distribution in an Insulated Metal Pipe Containing a Fluid Having a Given Thermal History

Investigator: John E. Brock, Professor of Mechanical Engineering

Sponsor: Unsponsored

Objective: To develop a method of solution for the thermal history in the wall of a metal pipe which is externally insulated and which is convectively exposed to fluid contents having given temperature, pressure, and flow as functions of time.

Summary: In electric power generating stations (particularly nuclear power plants) and in test facilities intended to expose elements intended for use in such stations to realistic environments, severe transients may result from "scrams" and other postulated events. Piping and vessels may experience severe thermal stress transients because of rapid variation in the temperature-pressure-flow conditions of their fluid contents. The wide range through which temperatures vary during such events vitiate the customary assumptions of constant physical properties of the piping material. Indeed there are significant variations of thermal conductivity (and other properties) during a typical transient. Furthermore, the classical solution for hollow cylinder geometry is quite inconvenient for routine calculation purposes even under the unrealistic assumption of constant properties. Accordingly, the appropriate nonlinear partial differential equation (accounting for nonconstant properties) has been derived for the case of axisymmetrical geometry (one space dimension, plus time) and has been expressed in the form of a set of difference equations, using a Crank-Nicolson scheme to assure stability. Results have been compared with theoretical results in a few idealized cases (constant properties). A digital computer program is used for the solution. Subroutines compute properties for superheated steam (the fluid contents presently incorporated) and for low chrome-moly pipe (P22) material. Applications include marine power plants.

Publications: None

Title: Dunkerley-Mikhlin Approximations for the Gravest Frequency of a Vibrating System

Investigator: John E. Brock, Professor, Mechanical Engineering Department

Sponsor: Foundation Research Program (6.2)

Objective: To sharpen and extend the method, usually known as "Dunkerley's Method" employed for obtaining a lower bound for the gravest frequency of a simple vibrating sound.

Summary: A method has been developed for analyzing discrete and/or continuous vibrating systems so as to obtain approximations of various degrees of accuracy for the gravest (nonzero) frequency of vibration. The treatment of cases involving rigid body modes is new, powerful, and particularly interesting in that it involves the compliance (flexibility) of a related system in which the rigid body modes are arbitrarily suppressed in an non-unique manner. Also new is the ability to obtain higher order approximations by iterating a certain matrix (in the discrete case) or by iterating a Green's function in the continuous case. The method has been applied to a number of cases having engineering significance. In particular some remarkably accurate and simple formulas have been developed for some useful cases of beam vibration.

Publications:

J. E. Brock, "Dunkerley-Mikhlin Estimates of Gravest Frequency of a Vibrating System," Journal of Applied Mechanics, Vol. 43, Series E, No. 2, June 1976 (Volume 98 of the Transactions of the American Society of Mechanical Engineering), 345-348.

J. E. Brock, "Asymmetric Moment Loading of Annular Elastic Plates," Journal of Applied Mechanics, Vol. 43, Series E, No. 2, June 1976 (Volume 98 of the Transactions of the American Society of Mechanical Engineers), 353-355.

J. E. Brock, "Dunkerley-Mikhlin Estimates of Gravest Frequency of a Vibrating System," Technical Report NPS59Bc75101, October 1975.

J. E. Brock, "DM Approximations for the Gravest Frequency of a Vibrating System," Technical Report NPS59Bc75111, November 1975.

Conference Presentations:

J. E. Brock, "Dunkerley-Mikhlin Estimates of Gravest Frequency of a Vibrating System," presented at the National Conference of Applied Mechanics, University of Utah, Salt Lake City, Utah, June 1976.

Title: Finite Element Methods in Structural Mechanics

Investigator: G. Cantin, Professor of Mechanical Engineering

Sponsor: Université de Technologie, Compiegnè, France

Objective: Teach Finite Element techniques to the Graduate students of the Universitè de Technologie In Compiegnè and participate in the research endeavors of these students.

Summary: The Fall quarter of 1974 and the Spring quarter of 1976 were spent in France to accomplish the stated objectives. Several short projects were completed and some results published by the students. One significant method was discovered to solve an iterto intractable difficulty of the F. E. method for structural problems. The method permits to satisfy stress boundary conditions with a considerable improvement of solutions in all the cases treated. The research is ongoing.

Publication: None

Title: Structural Integrity of Gas Turbine Caramic Components

Investigator: G. Cantin, Professor of Mechanical Engineering

Sponsor: Naval Ship Engineering Center

Objective: Gas turbine Caramic components must be able to sustain very high stress levels at high temperature under dynamic loading. These problems are very complex and require a group effort, so Professor Pucci and I have joined to provide consulting services to NAVSEC for this ARPA project, as well as conducting an independent study here at the Naval Postgraduate School for the solution of such problems.

Summary: The computation techniques of Airesearch Manufacturing Company of Arizona were critically reviewed and the results transmitted to NAVSEC, the first design review of the same contractor also took place last month and we participated actively in this process.

Publication: None

Title: Nonlinear Stress Strain Analysis

Investigator: G. Cantin, Professor of Mechanical Engineering

Sponsor: Naval Weapons Center

Objective: Determine whether available analytical technology (codes) could be used in the design of shells that could penetrate a substantial thickness of concrete and preserve some structural integrity. The load on the shell is explosive and the deformations and material behavior expected to be in the nonlinear range.

Summary: MARC CDC, NASTRAN, SAP IV and NONSAP all have advertised capabilities to do all or part of the preliminary studies. Our first task was to verify that the advertised capabilities really existed and that the codes could give reliable results for design usage. Two problems were defined and solutions obtained with all four systems. The comparison of results is ongoing and another system ADINA has been added to our study.

Publications: None

Title: Finite Element Formulation for Doubly Curved Shells

Investigator: G. Cantin, Professor, Mechanical Engineering Department

Sponsor: Foundation Research Program (6.2)

Objective: The objective of the project was to review results obtained by G. Fonder of the University of California at Berkeley, that contradicted similar results obtained here at the Naval Postgraduate School, by Dean Kiess, one of our graduate students.

Summary: The results of Kiess were reproduced and found to be seemingly correct. It was impossible to reproduce the results of Fonder and there are indications that his computations may be erroneous. The work is not finished and had to be abandoned for more urgent projects. The support received from the Foundation was returned to the Foundation.

Publications: None

Title: Synthesis of Advanced Marine Vehicles

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: To develop a computer program which provides for computer-aided synthesis of an advanced marine vehicle.

Summary: A modern navy has a variety of marine vehicles from which to choose including hydrofoil craft, capture air bubble, surface effect ships, submerged hull, conventional hull, multiple hull, and wing-in-ground-effect. Each class of vehicle has different trade offs which can be demonstrated by a realistic computer-aided synthesis program. One of the vehicle classes will be chosen for emphasis.

To initiate the work on the subject of advanced marine vehicle synthesis, a series of lecturers were invited from NAVSEC, NAVSEA, industry and universities. These lectures established a benchmark on current state-of-the-art. As a result, the thrust of NPS effort becomes clear and duplication of work done elsewhere is avoided.

One project initiated as a result of a preliminary work is the evolution of a remotely controlled minesweeper. Professor Fuhs visited MINRON 12 in Charleston, SC to coordinate the work. MINRON 12 has a direct interest in the remotely controlled minesweeper. The project extends into FY7T and FY77.

Publications: None

Title: Cylindrical Shockwave Diffuser for Gas Dynamic and Chemical Lasers

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To determine to what degree significant reductions in laser weight and volume can be achieved by use of cylindrical laser geometry. Prior to this investigation, a multiple-nozzle, cylindrical geometry had never been operated in supersonic flow with a cylindrical shock wave.

Summary: Apparatus using 4, 5, or 6 nozzle discs was designed. The discs were fed along the centerline from both ends of the stack. The design Mach number was 4.2. Boundary layer bleed was provided in both end walls. The cylindrical nozzles were installed in a plenum which had ejectors for control of the exit pressure. A cylindrical shock wave was established with a region of supersonic flow between nozzle exit and the shock wave. The shock wave was corrugated due to variations in stagnation pressure arising from nozzle boundary layers and wakes. In spite of extensive suction on boundary layer at end walls, the end flow channels were not started. The experiments were a success in that a stable cylindrical shock wave formed by a multiple disc nozzle array was demonstrated. More work is required to establish supersonic flow in the channels next to the end walls.

Publications: D. Donoghue and A. E. Fuhs, "Cold Flow Tests of a Multiple-Disc Cylindrical Nozzle with Shock Wave Diffuser," TRI-SERVICE CHEMICAL LASER SYMPOSIUM, AFWL, Kirtland AFB, NM, 18-20 Feb 1976.

Thesis Directed: D. Donoghue, "An Experimental Analysis of A Cylindrical Shock Wave for Use in a Cylindrical Gas Dynamic Laser," Master's Thesis, June 1975.

Title: Partial-Isentropic Laser Diffuser with Boundary Layer Bleed

Investigator: A. E. Fuhs, Professor of Mechanical Engineering, and LT Paul Habel, Graduate School

Sponsor: Naval Weapons Center

Objective: There are two objectives: To construct a diffuser with large pressure recovery by using isentropic diffusion from M = 3.5 to M = 2.3 and to determine the influence of boundary layer bleed at various locations in the diffuser.

Summary: Boundary layer bleed is common practice in aircraft inlets; bleed enhances pressure recovery. An experimental investigation has been conducted using a partial-isentropic diffuser with extensive boundary layer bleed. To determine the influence of location and amount of bleed, 35 different bleed circuits were incorporated. Any combination of end wall, side wall compression surface, throat etc. bleed was attained by selectively opening the appropriate valves.

The Mach number in the cavity was 3.5. Without bleed, the diffuser would unstart at a pressure ratio of 11 to 1, i.e., ratio of plenum to atmospheric pressure. With boundary layer bleed the minimum pressure ratio to maintain supersonic flow was 8.5 to 1. Bleed gives a significant improvement in diffuser pressure recovery.

An important result was found experimentally. Pressure at the diffuser throat is greater than in the cavity. It is possible to bleed the boundary layer in the critical throat region and inject the gas into the cavity. External bleed pumps are not required. Bleed in this manner has been termed self-activated bleed. Using self-activated bleed, the minimum pressure to maintain supersonic flow was reduced from 11 to 9. Use of self-activated bleed translates directly into a 20% reduction in the requirement for ejector propellants.

Contraction ratios greater than values reported in the literature (1.64 vs. 1.39) were achieved. To start the diffuser fast-acting, self-activated, mass bleed valves were used to remove mass from the cavity during start. Once supersonic flow is established, the valves close automatically.

Conference Presentations:	Paul Habel and A. E. Fuhs, "Influence of Mass and Boundary Layer Bleed on Starting and Pressure Recovery in Laser Diffusers," presented at the TRI-SERVICE CHEMICAL LASER SYMPOSIUM, AFWL, Kirtland AFB, New Mexico, 18-20 February 1976.
Thesis Directed:	Paul G. Habel, "A Study of Boundary Layer and Mass Bleed in a Short Length Supersonic Diffuser for a Gas Dynamic Laser," Master's Thesis, March 1976.

Title: Assessment of High Energy Laser Role on Future Navy

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command and Naval Weapons Center

Objective: To introduce operational experience into an assessment of potential of high-power lasers on board future Navy aircraft.

Summary: High-energy lasers (HEL) have not reached the level of technological maturity where selection of type of laser, optics, turrets, etc., is a straightforward process. Naval Air Systems Command (NAVAIRSYSCOM) wants to inject the operational experience of Naval Aviators into the selection process. For example, what about logistics of deuterium fluoride on an Attack Aircraft Carrier (CVA)? What does the carrier landing do to microradian optical alignment? Students involved in the project have a total of 50 man years of carrier experience with F-4, F-8, A-4, A-6, E-2, A-3, and A-5 aircraft. Initially a state-of-the art gas dynamic laser was designed and packaged for the S-3 A aircraft making it a S-3 L. A joint project was initiated with National Aeronautics Space Administration (NASA) Ames to design an aircraft for a laser platform. The aircraft is the largest aircraft that can be operated from the Navy's 12 carriers. The aim was to incorporate the laser giving the most intensity (kW/cm^2) at a specified range.

Other aspects of HEL on an aircraft have been investigated. The improvement in specific power achieved by use of regenerative heating of nitrogen in a Gas Dynamic Laser (GDL) has been assessed. Future pointing and tracking needs have been studied. An important classified mission for HEL has been investigated.

Publications: None

Thesis Directed: L. Rhine, "A Regeneration Carbon Dioxide Gas Dynamic Laser," Master's Thesis, June 1975.

Title: External Burning Assisted Projectile

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Naval Ordnance Station

Objective: To develop a fast subroutine to replace the unwieldy external burning assisted projectile (EBAP) computer code.

Summary:

In prior years a computer program was developed which predicts base pressure for supersonic conbustion in the region near the recirculation zone of a projectile. Validity of the predictions was established by a complementary experimental program. The computer program uses the saddle point singularity to uniquely select the base pressure. For trajectory analysis of an EBAP, base pressure is required as a function of Mach and Reynolds numbers.

To decrease computer time, selected combinations of values of input parameters have been used for determining base pressure. A regression analysis in several dimensions has yielded a subroutine which gives base pressure prediction in less than a second. Correctness of the predictions hinges on the full EBAP program. The subroutine is well suited for trajectory analysis.

A ramjet program has been developed for the HP9830 desk calculator for use by the personnel at the Naval Ordnance Station. The program models the inlet, combustion chamber and nozzle with base flow to obtain component efficiencies. Efficiencies are used to calculate specific fuel consumption, thrust coefficient and specific thrust. The program can be used in the NOS trajectory computer code. In FY 1975 the ramjet inlet and combustion chamber were modeled.

Another study initiated involves a comparison between guns and missiles. Under what conditions are guns the better weapon and under what conditions are missiles superior. Development of projectile propulsion alters the importance or range in selection of guns or missiles. There are many parameters to be evaluated including cost, time of flight, ordnance storage, response time, rate of fire, launch accuracy, etc.

Conference Presentations: A. Roberts and A. E. Fuhs, "Analysis of Propulsion for Gun Launched Projectiles," presented at the 12th Joint Army Navy Nasa Air Force (JANNAF) Propulsion Meeting, October 1975.

Publication: W. Smithey and A. E. Fuhs, "External Burning Assisted Projectile." (AIAA) Progress Series, Aerodynamics of Base Combustion, Volume 40, 1975.

Thesis Directed: W. Smithey, "Projectile Thrust-Drag Optimization with External Burning," PhD Dissertation, June 1974.

Title: Transonic Thermal Blooming of a Slewed High Energy Laser Beam

Investigator: A. E. Fuhs, Professor of Mechanical Engineering

Sponsor: Air Force Weapons Laboratory

Objective: To study the seriousness of thermal blooming near Mach one.

Summary: Due to absorption of radiation from a laser beam the index of refraction changes, causing spreading of the beam; this process is known as thermal blooming. When the beam is slewed, as it will be when tracking, there is a relative wind. Depending on the Mach number of the relative wind, the severity of thermal blooming varies. At precisely Mach one, the waves arising from heat addition add. In the linear theory the perturbation grows without limit. Nonlinear effects terminate the growth.

Near a Mach number of unity the equations of gas dynamics are nonlinear. Because the equations are nonlinear, systematic solutions are nonexistent. Many special techniques have been developed for airfoils; however, these methods are not applicable to distributed heat sources, i.e., heat from laser beam. A new approach was developed. Using the equations of gas dynamics in natural coordinates, the nonlinearity can be removed if streamline shape is specified. A pair of simple, first order partial differential equations result; these can be easily solved numerically. A check exists for choice of streamline shape; the check is the comparison of heat absorbed from the beam and the heat required to change flow properties. These two heat inputs must, of course, be equal. Streamline shape is adjusted until equality is achieved.

The research has shown that transonic thermal blooming is not as serious as originally feared.

Publications: A. E. Fuhs, "Propagation of Laser Beams Which are Rapidly Slewed," The Proceedings of the Electro-Optical Systems Design/International Laser 1975 Conference, Laser Institute of America, 1975.

E. Fenton Carey and A. E. Fuhs, "Transonic Thermal Blooming Due to an Intense Laser Beam," Journal of Aircraft, 13, pp 974-980, December, 1976.

Title: Second-Order Theory of Wave Interaction with Fixed Bodies

Investigator: C. J. Garrison, Associate Professor of Mechanical Engineering

Sponsor: National Science Foundation

Objective: The objective of this research is to develop a mathematically consistent, second-order perturbation theory for the determination of gravity wave interaction with large bodies of arbitrary shape. The final phase of the work will involve the experimental verification of the theory.

Summary: The development of the second-order theory of wave/body interaction has been completed. Both the first-order and second-order boundary value problems have been formulated and a numerical solution based on the use of a Green's function has been developed. A computer code has also been developed to carry out the numerical solution for the velocity, pressure distribution and overall forces acting on a semi-immersed body of arbitrary shape. The results of the work are directly applicable to the solution of practical problems involving the determination of the loading of offshore structures and are also of theoretical interest with respect to the general theory of free-surface hydrodynamics. This is a continuing project.

Conference Presentation: C. J. Garrison, "The Consistent Second Order Diffraction Theory," presented at the 15th Coastal Engineering Conference, July 11-17, 1976, Honolulu, Hawaii.

Title: Dynamic Response of Moored OTEC Plants to Ocean Waves

Investigator: C. J. Garrison, Associate Professor of Mechanical Engineering

Sponsor: Energy Research and Development Administration

Objective: This research has as objectives the analysis of the dynamic response of large flexible floating objects to ocean waves. A computer code will be generated as part of this project which will be used to study the dynamic response of floating OTEC plants. This analysis will include the high-frequency response to an ocean spectrum as well as the slow-drift response associated with the so-called steady-state drift force.

Summary: The development of Ocean Thermal Energy Conversion plants which will be moored in the ocean requires a knowledge of the dynamic response incuded by storm waves. Traditionally, naval architects have been concerned with the motion of the two-dimensional shiplike configuration; the floating OTEC plant poses new problems. Additionally, the mooring of large objects in the sea presents many new problems. Slow-drift oscillations occur and this low-frequency surging motion is very often the most critical factor in design because it may approach the natural frequency of the mooring system. This is a continuing project.

Conference Presentations: C. J. Garrison, "Dynamic Response of Floating Bodies," Paper No. OTC 2067 presented at the Offshore Technology Conference, Houston, Texas, May 1974.

Publications: C. J. Garrison, "Hydrodynamics of Large Objects in the Sea - Part I: Hydrodynamic Analysis," Journal of Hydronautics, Vol. 8, No. 1, Jan. 1974.

C. J. Garrison, "Hydrodynamics of Large Objects in the Sea - Part II: Motion of Free-Floating Bodies," Journal of Hydrodynamics, Vol. 9, No. 2, April 1975.

Title: Drag and Inertia Coefficients in Oscillatory Flow About Cylinders

Investigator: C. J. Garrison, Associate Professor of Mechanical Engineering

Sponsor: Unsponsored

Objective: The objective of this work is the experimental determination of the coefficients of drag and inertia in oscillatory flow about both smooth and rough circular cylinders. Emphasis was placed on the correlation of these two coefficients with Reynolds number and the relative amplitude of the motion and extending this correlation into the large Reynolds number range of interest in practice.

Summary: Experiments were conducted using a water channel 16 feet long, 4 feet deep and 2 feet wide. A circular cylinder which spanned the distance between the two walls of the channel was oscillated in harmonic motion by use of a carriage connected to an eccentric drive wheel. Several tests have been carried out for both a smooth and rough cylinder and the resulting values of the drag and inertia coefficients correlated with the Reynolds number and relative amplitude of the motion (amplitude to diameter ratio). In the case of the smooth cylinder, the Morison equation was found to represent the measured force/time relationship; satisfactorily and highly useful correlations of the drag and inertial coefficients were produced. These results extend into the large Reynolds number range and, accordingly, are of great importance in application. The results obtained using a rough cylinder were not well-represented by use of the Morison equation within the range of the experiments. This area will be studied further in the future; this is a continuing project.

Conference Presentations: C. J. Garrison, "Drag and Inertia Coefficients in Oscillatory Flow About Cylinders," Paper No. 2693, presented at the American Society of Chemical Engineers' National Water Resources and Ocean Engineering Convention, San Diego, California, April 5 - 8, 1976.

Title: LPG Feed System Dynamics

Investigator: T. M. Houlihan, Associate Professor of Mechanical Engineering

Sponsor: Naval Ordnance Station, Indian Head

Objective: A computer model was to be developed to simulate a projectile ram-propellant feed system for a Liquid Propellant Gun.

Summary: Using a lumped parameter approach, a set of simultaneous differential equations was derived for the interaction of propellant fluid, driving injector and projectile. The computer model was verified against a 20mm experimental apparatus. System parameters affecting projectile ram time and chamber pressure oscillations were investigated.

Publication: Dampier, C. R. and Houlihan, T. M., "Computer Simulation of an LPG Propellant Feed System," Technical Report, NPS 69Hm76091, September 1976.

Title: A Study of the Secondary Flow in a Curved Rectangular Channel

Investigator: M. D. Kelleher, Associate Professor, Mechanical Engineering Department

Sponsor: Foundation Research Program (6.2)

Objective: The objective of this work has been to study the structure of the secondary motion induced by centrifugal forces in a curved channel of large aspect ratio. The study was carried out using a hot wire anemometer system which was capable of traversing in two directions over the channel cross section.

Summary: The apparatus for the present study consists of a plexiglas channel with a contraction inlet followed by a straight section 122 cm. long. This is then followed by the curved test section. The flow is maintained by suction from a centrifugal blower. A rotometer is installed between the outlet of the test section and the blower. The flow cross section is 0.635 cm by 25.4 cm for an aspect ratio of 40. The straight section immediately down stream of the inlet nozzle is of sufficient length for the flow to be fully developed before entering the curved section. With the high aspect ratio of the flow cross section the flow is essentially two dimensional Poiseuille flow before entering the curved section. The curved section of the channel turns through 180 degrees with the radius of curvature of the outer (concave) wall being 30.48 cm and the radius of the inner (convex) wall being 29.84 cm. The hot wire anemometer traverse is mounted through the convex wall at a location 135 degrees downstream of the start of the curved section.

This traverse mechanism is free to move in both the spanwise direction and the radial direction across the channel gap. The movement in the spanwise direction is controlled by a DC Stepper motor and sweep drive unit. With this system the speed of traverse could

be controlled over a very wide range. For these experiments the spanwise traverse was run at a speed of 0.85 mm/sec. The output from the sweep drive unit also served as a linear displacement transducer which indicated the spanwise position of the hot wire probe. The movement in the radial direction is controlled by a hand operated micrometer unit. Although the traverse mechanism was capable of sweeping 15.24 cm in the spanwise direction, during the actual measurements it was found that a 5.0 cm traverse gave good results. With the relatively slow traverse speed of 0.85 mm/sec. a single traverse required approximately one minute.

The velocity surveys were made as follows: the blower for the channel was set to provide the desired flow rate. With the traverse set at the initial spanwise position the hot wire probe was set at the desired radial position by means of the micrometer. After the initial position of the hot wire probe has been established the sweep drive mechanism was turned on to begin the automatic traverse of the hot wire across the channel. When the 5 cm traverse was completed the traverse was reversed to return the probe to its original position. The radial position was then changed by 0.635 mm by adjusting the micrometer setting and a new traverse was begun. The procedure was continued until the probe was at a position 0.635 mm from the concave wall. This was the closest position for traversing the hot wire probe. The data was recorded directly on an x-y plotter. The output from the sweep drive unit representing spanwise displacement was recorded on the x axis and the linearized signal from the hot wire probe representing velocity was recorded on the y axis. The velocity surveys were conducted for three different flow rates corresponding to Dean numbers of 79.2, 94.9, and 113.5. In each of these cases spanwise velocity traverses were made at six different radial positions. The periodic nature of the secondary flow is clearly illustrated. As would be expected the amplitude of the periodic motion is greatest in the region close to the concave wall. It is interesting to note that the velocity

profile on the convex side of the mid-plane is 180 out of phase with the velocity profile on the concave side of the mid-plane. This is similar to the phenomenon observed by Shubaur and Skramstad in their measurement of the Tollmien-Schlichting waves in the boundary layer on a flat plate. In the sense that the mid-plane is the location across which the phase reversal takes place, it is similar to the critical layer for Tollmien-Schlichting waves. The phase shift is present at all three Dean Numbers. Average values of the wave number were calculated from the velocity profiles for the three Dean Numbers.

Publications: None

Title: Effects of Gravity on Gas-loaded Variable Conductance Heat Pipes

Investigator: M. D. Kelleher, Associate Professor of Mechanical Engineering

Support: National Science Foundation

Objective: To investigate the effects of gravity on the performance of gas-loaded, variable conductance heat pipes in which noncondensible gas and the working fluid are of significantly different molecular weights. The investigation is concerned with the nature of the vapor-gas interface region, particularly the phenomena associated with the vertical and horizontal operating positions.

Summary: The design procedures and analytical tools, which have so far been developed to predict the performance of gas-loaded heat pipes, do not consider many of the circumstances in which the gravitational field could have a profound effect on their operation. The situation in which the molecular weights of the working fluid and the non-condensible gas are very different is one in which the effects of gravity must be given careful consideration.

Three heat pipes have been built and tested, 1.6 cm diameter, 2.5 cm diameter and 5.0 cm diameter. Each heat pipe is equipped with two pressure transducers, one at the evaporator end and one at the condenser end. In addition, each heat pipe has two stainless steel sheathed thermocouples which penetrate 1.25 cm into the evaporator and condenser of each pipe. Each heat pipe has 24 surface thermocouples spaced at 5 cm intervals along the adiabatic and condenser-reservoir sections. Each heat pipe has also been coated with temperature-sensitive encapsulated liquid crystals so that any deviations from one-dimensional behavior of the temperature distribution could be observed.

Each pipe has been operated using methanol as the working fluid and in the variable conductance mode using both krypton and helium as the non-condensible gases. Each heat pipe has been operated in both the horizontal and the vertical (condenser up) mode.

It has been demonstrated that orientation in the gravitational field can have a serious effect on the operation of gas-loaded heat pipes in which the working fluid and noncondensible gas are of significantly different molecular weights. For the smallest

diameter pipe (1.6 cm) the effect of gravity is to distort and displace the vapor-gas interface region while not seriously effecting the basically one-dimensional nature of the transport processes within the pipe.

For the larger diameter pipes (2.5 cm and 5 cm) of gravity are more profound. In the horizontal operating position stratification of the working fluid vapor and noncondensible gas occurs. The vapor and gas separate into horizontal layers. In this case the transport processes inside the pipe are highly three dimensional. In the vertical position with the larger diameter pipes gravity induces a distortion of the vapor-gas interface region which is more severe than for the smaller pipe.

No attempt has been made to determine what role other factors such as capillary pumping or wall conduction might play in the observed phenomena. It has been assumed that the large molecular weight differences were the dominant factor.

Publications:

M. D. Kelleher and W. H. Batts, "Effects of Gravity on Gas-loaded Variable Conductance Heat Pipes," Proceedings of the Second International Heat Pipe Conference, Bologna, Italy, April 1976.

Title: Heat Transfer Enhancement in Naval Condensers

Investigator: P. J. Marto, Associate Professor of Mechanical Engineering

Sponsor: Naval Sea Systems Command

Objective: To examine current design procedures for Naval condensers, and perform a feasibility study of enhanced heat transfer designs, comparing weight, volume, life-cycle cost, etc. Evaluate current state-of-the-art of heat transfer augmentation techniques in condensers, including the promotion of dropwise condensation on the vapor side. Conduct heat transfer research and exploratory development in an effort to increase the overall condenser heat transfer coefficient U in a reliable manner.

Summary: An extensive literature review has been completed, with a wide variety of references, including patents, on dropwise condensation. Correspondence with active researchers in condensation heat transfer has been initiated including researchers at UC - Seawater Conversion Lab, Oklahoma State University, NSRDC (Annapolis) and Queen Mary College (London).

Visits with personnel at NAVSEA, NAVSEC, NSRDC, as well as De Laval (Florence, N. J.) and Westinghouse (Sunnyvale, CA), have attempted to examine present condenser designs and the need for compact condensers aboard surface ships and submarines.

A feasibility design study of marine compact condensers is near completion. The study uses a computer program titled ORCON, developed by the Oak Ridge National Laboratory, which permits design modifications to be made including enhanced heat transfer on the steam and seawater side of the condenser. Possible weight, volume and life-cycle cost payoffs are being tabulated.

The design and construction of an experimental test facility is now underway. The test section will facilitate operation over a range of input variables such as cooling water velocity, steam velocity and direction, and non-condensible gas concentration. Condensation heat transfer data will be obtained for different tube materials, tube geometries and condenser modes. The effect of ship roll/pitch on overall performance can also be studied.

Publications: None

Title: Performance Characteristics of Rotating Wickless Heat Pipes

Investigator: P. J. Marto, Associate Professor of Mechanical Engineering

Sponsor: Naval Sea Systems Command

Objective: To understand the operating characteristics and to predict the heat transfer performance capabilities of rotating wickless heat pipes as used to cool rotating machinery components.

Summary: A theoretical model was derived for laminar film condensation on the inside of a rotating, truncated cone. Nusselt's classical analysis was modified to include effects of vapor shear and vapor pressure drop. Performance characteristics have been studied for a variety of operating conditions.

An improved experimental apparatus has been designed and constructed. A variety of copper condenser sections will be tested using water, ethyl alcohol, and Freon 113 in order to study heat transfer augmentation techniques in the presence of high gravity fields.

Conference Presentations: P. J. Marto, "Performance Characteristics of Rotating, Wickless Heat Pipes," Presented at 2nd International Heat Pipe Conference, Bologna, Italy, 1976.

Title: Nucleate Boiling in Thin Liquid Films

Investigator: P. J. Marto, Associate Professor of Mechanical Engineering

Sponsor: None

Objective: To provide additional experimental data on this mode of heat transfer in order to further understand the complex processes which occur when bubbles form, grow and depart from a heated surface.

Summary: Experimental results have been obtained for distilled water, ethyl alcohol and Freon 113 at atmospheric pressure with liquid levels ranging from normal pool depths down to thin films near 0.5 mm. Temperature measurements with thermocouples and liquid crystals show that liquid level has little effect on the heat transfer coefficient above a level of 5 mm. Below this level, however, there is an increase of up to 50 percent in the heat transfer coefficient as level is reduced, until dryout occurs. Additional tests are being run to study the effect of heater material and roughness on this phenomena.

Publications: P. J. Marto, LT D. K. Mackenzie, USN, and LT A. D. Rivers, USN, "Nucleate Boiling in Thin Liquid Films," AICHE Paper No. 16, 16th National Heat Transfer Conference, St. Louis, August 1976.

Title: Transient Response of Submerged Structures Subjected to Blast Loading

Investigator: R. E. Newton, Professor, Mechanical Engineering Department

Sponsor: Foundation Research Program (6.2)

Objective: To demonstrate the capabilities and limitations of the finite element method (FEM) in studying the transient response of submerged structures subjected to blast loading. This is a continuing project.

Summary: The first phase of this investigation was reported by D. L. Atchison in his thesis. He showed that the problem could be separated into a study of the propagation of a blast wave past a fixed rigid obstacle and a study of the motion of a submerged structure under loadings found in the propagation study. He also demonstrated that FEM gives satisfactory results for the two-dimensional problem of the propagation of a plane-fronted acoustic blast wave past a circular cylinder with axis parallel to the wave front.

The current phase of the investigation has dealt with the corresponding response motion of an infinitely long, ring-stiffened elastic cylinder having uniformly spaced elastic bulkheads. This problem is resolved into two-dimensional sub-problems by using Fourier series representation of the circumferential variation of fluid pressure and structural displacement. FEM solutions of the sub-problems are superposed to find resulting deflections and stresses. The critical combinations of blast pressure and submergence pressure, just sufficient to produce shell collapse, have been determined.

Publications: R. E. Newton and D. L. Atchison, "Response of a Ring-Stiffened Cylinder to an Acoustic Blast Wave," Proceedings of the Second International Symposium on Finite Element Methods in Flow Problems, Santa Margherita, Italy, June 1976.

Thesis Directed:

D. L. Atchison, "Finite Element Solution of the Interaction of a Plane Acoustic Blast Wave and a Cylindric Structure," Master's Thesis, June 1974.

Title: Nuclear Reactor Dynamics With Temperature Dependent Feedbacks

Investigator: D. H. Nguyen, Associate Professor, Mechanical Engineering Department

Sponsor: Foundation Research Program (6.1)

Objective: To obtain solutions of Nonlinear Space-Time Reactor Dynamics Problems

Summary:

The explicit inclusion of temperature dependent feedbacks results in nonlinear neutron transport problems. The one-velocity, space-time dependent diffusion equation has been solved, using the finite element method, for the multiregion reactor system under highly discontinuous initial disturbances. The space dependence of fast reactor dynamics under such conditions has been examined.

The multi-group space-time dynamics problem has also been solved under uniform initial disturbances. The method used is the Newton-Raphson-Kantorovich iterative technique applicable to operator equations. The space discretization is achieved by finite element method, and the resulting set of stiff ODE is integrated by a modified Gear's method. The results show a very fast rate of convergence. The cost in terms of computer time and storage is well within reasonable limits, so that the method is attractive for the analysis of real systems.

Publications:

Dong H. Nguyen, "Finite Element Solutions of Space-Time Nonlinear Reactor Dynamics," Nuclear Science and Engineering, 60, pp. 120-130, (1976).

Dong H. Nguyen, "Space-Time Solutions of Multigroup Nonlinear Reactor Dynamics Equations," Transactions of the American Nuclear Society, 23, p. 590, (1976).

Conference Presentation:

Dong H. Nguyen, paper presented at the 1976 Joint Meeting of the American and Canadian Nuclear Societies, Toronto, Canada. (June, 1976).

Title: Corrosion Studies on Zinc Anode Materials

Investigator: J. Perkins, Associate Professor of Mechanical Engineering

Sponsor: Foundation Research Program (6.2)

Objective: To determine the environmental and materials-related electro-chemical factors which determine corrosion film structure and morphology and corrosion kinetics for zinc anodes in sea water. The study is intended to shed light on the common problem of passivation of sacrificial zinc anodes, which renders them useless in their role as protection for structures such as ships' hulls and ocean platforms.

Summary: Scanning electron microscopy has been used extensively in the study of the morphology of anodic corrosion products formed under controlled electrochemical conditions in sea water electrolyte. Interest in this area is stimulated by the common naval use of zinc alloys as sacrificial galvanic anodes for cathodic protection of ship hulls. A common problem associated with this usage has been the development of apparent anode passivity, and therefore loss of protection due to current blockage. The Naval Postgraduate School (NPS) program was initiated with the aim of delineating the electrochemical and metallurgical features that are critical in this regard. Direct observation techniques have proved to be fruitful in following the mechanism of film formation. The general film structure consists of an array of zinc oxide (ZnO) crystallites nucleated with a population density on the order of 10^6 plates/cm^2. This represents a macroscopically porous and nonpassive film condition for the zinc anode. The crystallography growth mechanism, and kinetics of development of such films is being studied in detail utilizing microscopy, x-ray diffraction, and energy-dispersive x-ray analysis. Laboratory experiments are being conducted to delineate critical ranges of various electrochemical variables, including current density and velocity effects.

Publications:

R. A. Bornholdt and Jeff Perkins, "SEM Examination of Corrosion Product Morphology for Anodically Polarized Zinc," Metallography, 8 (1975) 401-409.

J. Perkins and R. A. Bornholdt, "Corrosion Product Morphology in Anodic Electrocrystallization of Zinc Oxide on Zinc in Sea Water," Corrosion Science (in press).

J. M. Todd and J. Perkins, "Corrosion of Zinc Anodes in Sea Water," Naval Engineers Journal (in press).

J. M. Todd and J. Perkins, "Nucleation and Growth of Anodic Electrocrystallization Products on Zinc in Sea Water," Corrosion, (in press).

J. Perkins, "Growth of ZnO Crystals During Anodic Electrocrystallization," Journal of Crystal Growth (in press).

J. Perkins, W. H. Luebke, and J. M. Todd, "Anodic Corrosion of Zinc Alloys in Saltwater," TMS-AIME Fall Meeting 1976, Niagara Falls, NY, Sept. 20-23, 1976.

Theses Directed:

J. M. Todd, "Nucleation and Growth of Anodic Electrocrystallizied Products on Ship Hull Zinc in Saltwater Solutions," Mechanical Engineer Thesis, December 1975.

J. M. Price, "A Potentiokinetic Determination of Corrosion Rules in Artificial Seawater-Hypochloride Solutions," Master's Thesis, June 1976.

W. H. Luebke, "A Scanning Electron Microscope Study of the Effects of Anode Velocity and Current Density on the Corrosion of Ship Hull Zinc in Synthetic Seawater," Master's Thesis, June 1976.

Title: Materials Approaches to Ship Silencing

Investigator: J. Perkins, Associate Professor of Mechanical Engineering

Sponsor: Naval Sea Systems Command

Objective: To investigate experimentally and analytically materials and design factors affecting sound and vibration in shipboard structures and machinery, and to evaluate candidate alloy materials with regard to damping properties as a function of metallurgical processing, applied stress, temperature, and vibration frequency.

Summary: Mn-Cu alloys have been evaluated in detail; these alloys develop very high damping capacity after proper heat treatment; the attainment of this quality is found to be quite sensitive to heat-conditions and to stress during heat treatment. Various methods of evaluating the damping of high-damping materials have been evaluated, and the fatigue performance of these alloys has been determined.

Resistivity measurements and internal friction have been utilized to study mecrostructural changes associated with the acoustic damping. Results have shown that properly treated Incramute I (a commercial Cu-Mn alloy) can develop a specific damping capacity (SDC) as much as four times that of grey cast iron, a material commonly used in heavy industry because of its relatively good damping characteristics. It has been found that SDC is sensitive to stress applied during heat treatment or in service. Results indicate a correlation between resistivity and low-stress SDC, and show that uniaxial tensile stress, applied during either the age or the quench, interferes with the development of high SDC.

Publications: None

Thesis Directed: F. L. Youngblood, "Characterizing and Controlling the Metallurgical Properties of a Cu-Mn Alloy for Ship Silencing Applications," Master's Thesis, June 1975.

Title: Fouling of Heat Exchangers

Investigators: Paul F. Pucci, Professor of Mechanical Engineering
James A. Miller, Associate Professor of Aeronautics

Sponsor: Naval Ship Research and Development Center

Objective: Survey of information (both literature and industry) on fouling caused by gas turbine exhausts.

Summary: This program was done by Professor Miller. He surveyed the literature and visited or telephoned manufacturers, users and laboratories concerned with this problem. He wrote a final summary report and forwarded it to the sponsor on 8 April 1976.

Publications: None

Title:	Fouling of Marine Gas Turbine Waste-Heat Systems
Investigator:	Paul F. Pucci, Professor of Mechanical Engineering
Sponsor:	Naval Ship Research and Development Center
Objective:	Assist NAVSEC and NSRDC in the definition of those parameters affecting the fouling of marine gas turbine wast-heat systems.
Summary:	Initial conferences with sponsors and with some industrial manufacturers led to the initiation of another project. (See Fouling of Heat Exchangers - Pucci and Miller)
Publications:	None

Title:	Optimized Ship Exhaust Eductor
Investigator:	Paul F. Pucci, Professor of Mechanical Engineering
Sponsor:	Naval Ship Research and Development Center
Objective:	To assist in the design of shipboard gas turbine exhaust eductors by constructing and testing scale models.
Summary:	The test facility for testing exhaust eductor systems was designed and construction begun. A scale model of an existing shipboard exhaust system was designed. Project continued into FY77.
Publications:	None

Title: Fluidic Concepts Evaluation

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To investigate low-frequency noise in fluidic elements and to relate the results of this investigation to NAVAIR development objectives.

Summary: Experience has shown that a wide range of frequencies may be generated in fluidic devices. The high frequencies do not generally present difficulties but low frequencies (i.e., those below 1000 Hz and particularly below 100 Hz) pose problems in the fluidic sensors and circuits being developed for fluidic guidance and control systems. This noise which is associated with various fluid dynamic phenomena, is a limiting factor in optimizing the low-level signal performance of many fluidic components and circuits, particularly analog-type devices. The present investigation dealt with a survey of the previous noise studies, definition of the noise and its related properties, and the design and construction of variable geometry amplifiers and the use of hot-wire anemometer techniques to obtain velocity and noise profile measurements.

The second part of the concept evaluation concerns the design of circulation control rotors (CCR) and the use of fluidic elements in achieving circulation control in helicopters with rigid blades. The section lift, drag, and moment coefficients at any angle of attack has been expressed in terms of five independent flow variables and six main geometric parameters. The flow variables are the momentum coefficient, mass flow coefficient, jet Mach number, free-stream Mach number, and the Reynolds number. The primary geometric parameters are profile family, thickness ratio, slot height to trailing-edge radius ratio, camber, trailing-edge radius to chord ratio, and the slot chordal position. The optimization of the hover and flight performance of the vehicle in terms of these parameters requires a detailed analysis of the blade dynamics and the design of a novel CCR control valving which will minimize vibrations, ballistic damage, and the number of movable parts. A comprehensive analysis has been carried out to achieve these objectives and a non-moving part CCR control valving has been designed.

Publications:

T. Sarpkaya, "On the Art of Advancing the Science of Fluidics," Journal of Dynamic Systems, Measurements, and Control, 95 (1975).

T. Sarpkaya, "Investigation of the Characteristics of Semi-Confined Laminar Jets," Technical Report, NPS-59SL76052, 1976.

Title: Cable Strumming in Cross Current - Analysis and Experiments

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: Civil Engineering Laboratory

Objective: To extend Sarpkaya's two-dimensional potential flow model to circular cylinders oscillating longitudinally and/or transversely to the flow, for the purpose of determining added mass, lift, and drag coefficients for oscillating cylinders. Also, to initiate laboratory experiments to check and validate the analytical model.

Summary: Elastic structures of one or more degrees of freedom can extract energy from the flow about them and can develop catastrophic flow-induced oscillations. The understanding of this energy-transfer process is of paramount importance if one is either to eliminate or minimize it or to design the elastic structure in such a manner that it can withstand the oscillations under the contemplated environmental conditions.

The discrete-vortex model has been applied to the determination of the flow characteristics about cylinders undergoing in-line and transverse oscillations. The results have been expressed in terms of a mean drag coefficient, and Fourier-averaged drag and inertia coefficients. The variations of these coefficients with Reynolds number, period parameter, and the relative amplitude of oscillations have been determined. Experiments have been carried out in a water tunnel with circular cylinders, and the coefficients cited above have been evaluated and compared with those obtained analytically. The results have shown that the mean flow has significant effects on the various coefficients, and that the results of experiments with harmonic oscillations in a fluid otherwise at rest are not applicable to oscillations of a cylinder in a uniform flow.

Publications: T. Sarpkaya, "An Analytical and Experimental Study of the In-line and Transverse Oscillations of a Circular Cylinder in Uniform Flow," Technical Report NPS59S175051, May 1975.

Theses Directed: J. T. Fry, "Harmonic Motion of Cylinders in Uniform Flow," Master's Thesis, June 1975.

Paulo Arruda Raposo, "Transverse Oscillations of a Cylinder in Uniform Flow," Master's Thesis, June 1976.

Donald Fortik, "Forced Oscillations of a Cylinder in Uniform Flow," Master's Thesis, June 1976.

David W. Meyers, "Transverse Oscillations of a Circular Cylinder in Uniform Flow," Master's Thesis, December 1975.

Title: Unsteady Flow About Bluff Bodies

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: National Science Foundation

Objectives: To determine the forces acting on bluff bodies immersed in time-dependent flows.

Summary: Experiments were conducted in a recirculating water tunnel, in a small U-shaped water tunnel, and a large U-shaped water tunnel with smooth and rough circular cylinders and spheres in the range of Reynolds numbers from 5,000 to 1,000,000. The velocity in the water tunnel consisted of a harmonically oscillating component superposed on a mean velocity. The drag and lift coefficients have been determined in terms of the Reynolds number and the appropriate flow parameters. The velocity in the U-shaped tunnels consisted of a purely harmonic oscillation. The lift, drag, and inertia coefficients have been determined in terms of the Reynolds number, period parameter, and the relative roughness.

A potential flow model of two-dimentional vortex shedding behind bluff bodies was developed. The free shear layers which emanate from the sides of the body were represented by discrete vortices through the use of the appropriate complex-velocity potential and the Joukowsky transformation between a circle and the body cross-section. The analysis was then applied to predict the Kinematic and dynamic characteristics of the flow for various flow parameters.

Publications:

T. Sarpkaya, "An Inviscid Model of Two-Dimensional Vortex Shedding for Transient and Asymptotically Steady Separated Flow Over an Inclined Plate," Journal of Fluid Mechanics, 68, Pt. 1 (1975).

T. Sarpkaya, "Forces on Cylinders Near a Plane Boundary in a Sinusoidally Oscillating Fluid," Fluid Mechanics in Petroleum Engineering, American Society of Mechanical Engineers, 1975, pp. 45-52.

T. Sarpkaya, "In-Line and transverse Forces on Cylinders in Oscillatory Flow at High Reynolds Numbers," Proceedings of the Offshore Technology Conference, OTC-2533, May 1976.

T. Sarpkaya, "Vortex Shedding and Resistance in Harmonic Flow About Smooth and Rough Circular Cylinders at High Renolds Numbers," Technical Report No. NPS-59SL76021, 2 February 1976.

Thesis Directed: Neil Jon Collins, "Transverse Forces on Smooth and Rough Cylinders in Harmonic Flow at High Reynolds Numbers," Master's and Engineer's Degree Thesis, June 1976.

Title: Prediction of Forces and Moments Acting on Bodies of Revolution at Large Angles of Attack

Investigator: T. Sarpkaya, Professor of Mechanical Engineering

Sponsor: Naval Air Systems Command

Objective: To develop a reliable numerical computation method to determine the asymmetric flow field of a body of revolution moving at high angles of attack, including the prediction of the forces and moments.

Summary: The vortex sheets emanating from the sides of the body have been represented by discrete vortices. This procedure has been combined with the cross-flow analogy or the impulsive flow analogy and applied to the analysis of asymmetric vortex shedding behind cylinders of increasing radius. Normal force, pitching moment and yawing force coefficients have been caculated for slender bodies with various nose fineness ratios at Mach numbers less than about 0.9. The analytical results will be combined with those obtained experimentally.

Experiments will be carried out in a vertical water tunnel capable of generating impulsively started uniform flows at various Reynolds numbers. The in-line as well as the side forces will be measured and correlated with the instantaneous position of the shed vortices.

Publications: T. Sarpkaya, "Comments on the Theoretical Study of Lift Generated Vortex Wakes Designed to Avoid Rollup," American Institute of Aeronautics and Astronautics Journal, Vol. 13, No. 12, December 1975.

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